A STUDY TO DETERMINE

THE OPTIMAL METHOD OF SCHEDULING RADIOLOGICAL EXAMINATIONS DURING THE ELECTRICAL-MECHANICAL UPGRADE PROJECT AT MUNSON ARMY COMMUNITY HOSPITAL

A Graduate Research Project

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This study was done to determine the optimal method of scheduling radiological examinations during the electrical-mechanical upgrade (EMU) project at Munson Army Community Hospital Fort Leavenworth, Kansas.

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Robin, my wife, put up with my consternations and complaints. Together, we learned the truthfulness of our credo, "It always takes longer than you think."

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I. INTRODUCTION

CONDITIONS WHICH PROMPTED THE STUDY

The demand for radiological examinations at Munson Army Community Hospital (MACH), Fort Leavenworth, Kansas, routinely exceeds the capacity of the Radiology Department because of an insufficient number of functional examination rooms. Patients and physicians complain about excessive waiting times for x-rays. Large backlogs of requests for fluoroscopic and other special radiological examinations are common. Scheduled appointments for these examinations are often booked for more than a month in advance. A new scheduling policy was initiated in October 1985 in an effort to hold the backlog of examination requests to an acceptable level. Physicians requesting examinations are to designate the maximum time the patient can wait for an appointment. If an appointment is not available within that time period, the patient is automatically sent to another hospital--usually the Veterans Administration Medical Center (VAMC) in Leavenworth or the Kansas University Medical Center (KUMC) in Kansas City--to undergo the examination. MACH pays for these examinations with Supplemental Care funds.

When the proposal for this study was initially developed in May 1985, MACH had two functional examination rooms equipped with General Electric and Siemens x-ray machines. A Phillips x-ray machine was on hand for placement in a third room which

was to have been completed by June 1985.

MACH expected the addition of a third examination room to reduce patient waiting time, the backlog of examination requests and the expenditure of Supplemental Care funds for examinations at other facilities. However, the benefits of the Radiology Department's expanded capacity were to be short-lived because of the Electrical-Mechanical Upgrade (EMU) project at MACH. Renovation of the Radiology Department under the EMU project is scheduled to begin in August 1986. The examination rooms are to be closed for renovation, one at a time, for a period of three months each. As a result, the Radiology Department was expected to again function with only two examination rooms from August 1986 to May 1987.

MACH never attained three functional examination rooms. Numerous problems, including an inadequate site preparation survey and the bankruptcy of a contractor, delayed the construction of the Phillips room. To make matters worse, the Siemens machine broke down in October 1985, leaving MACH with only the General Electric machine functional. The Siemens machine had a history of frequent mechanical failures, and repairs to make it fully operational would have cost $40,000. Since a replacement for the Siemens machine was already programmed in the Medical Care Support Equipment (MEDCASE) program, it was decided not to repair the Siemens machine and to expedite procurement of a replacement machine. Delivery and installation of a Picker x-ray machine to replace the Siemens

machine was expected by March 1986.

Problems with room construction and installation of the Phillips machine and delays in the procurement and installation of the Picker machine have continued since October 1985. The Phillips machine is now expected to be operational in June 1986. The Picker machine is expected to be operational by November 1986.

The Radiology Department has functioned with only the General Electric x-ray machine since October 1985. Although the Phillips room will be operational in June, it will be closed for the EMU renovation project in August, so the Radiology Department will again function with only the General Electric machine during the first three months of the project. The Phillips and Picker rooms will be operational during the second three-month period, and the Phillips and General Electric rooms will be operational during the final three months of the project.

During the EMU project, the backlog of examination requests will still be controlled by the policy that automatically sends patients to other hospitals when an appointment is not available within the time frame specified by the physician requesting the examination. MACH wants to minimize the expenditure of Supplemental Care funds for radiological examinations by maximizing the number of examinations done in-house. However, the hospital does not want to do so many examinations in-house that the patient waiting times are excessive. The Radiology

Department needs an examination scheduling method that minimizes expenditures on examinations done at other hospitals and adequately controls waiting times for examinations done at MACH.

PROBLEM STATEMENT

To determine the optimal method of scheduling radiological examinations during the electrical-mechanical upgrade (EMU) project at Munson Army Community Hospital, Fort Leavenworth, Kansas.

OBJECTIVES

1. Analyze the current method of scheduling radiological examinations.

2. Quantify parameters that describe the current operation of the Radiology Department.

3. Estimate the radiological workload that is expected during the EMU project.

4. Identify the constraints that are expected to affect the service capabilities and examination scheduling methods of the Radiology Department during the EMU project.

5. Based on a literature search and consideration of the information obtained above, identify alternate examination scheduling methods.

6. Estimate the longest average waiting time that is expected during the EMU for patients arriving within a one-hour

period, given the alternate scheduling method.

7. Given the constraints associated with the alternate scheduling methods, use linear programming to determine the number and mix of examinations to be scheduled at MACH that will minimize the expenditure of Supplemental Care funds for examinations to be performed at other hospitals.

CRITERIA

1. The optimal scheduling method will result in a longest expected average waiting time for patients arriving within a one hour period that is less than or equal to the maximum acceptable average patient waiting time set by the Chief of the Radiology Department. This criterion takes precedence over subsequent criteria.

2. The optimal scheduling method will schedule the number and mix of examinations to be done at MACH that will result in the lowest projected expenditure of Supplemental Care funds for examinations to be performed at other hospitals as determined by linear programming.

3. If projections indicate that more than one alternate scheduling method will accomodate the entire projected examination workload, the optimal scheduling method is that method which, in the opinion of the Chief of Radiology, is the most convenient for the Radiology Department to utilize.

ASSUMPTIONS

1. Staffing levels and the productivity of personnel in the Radiology Department will not change significantly from their current levels during the EMU project.

2. There will be no major changes in the radiological equipment utilized.

3. Data concerning the time required to perform a given procedure with the General Electric machine can be applied to the Picker and Phillips machines. This assumption is necessary because the General Electric machine will be the only machine in operation during the study period.

4. Unless it is altered by the alternate scheduling method, the hourly pattern of patient arrivals in the Radiology Department will be the same during the EMU project as that observed in the study period.

LIMITATIONS

1. The study is limited to investigating changes in the method of scheduling radiological examinations. The study will not address measures to increase the productivity of the individuals in the radiology department.

2. For a given method of scheduling examinations, the estimation of the expected average waiting times during the EMU (Objective 6) would ideally be determined with a queuing model

or computer simulation.[1] The complexity of a queuing model that would be applicable to this study precludes the use of the model by the student. Computer simulation techniques will not be used in this study, because the student lacks the expertise, time and computer support necessary to develop a computer simulation program.

LITERATURE REVIEW

A review of the literature revealed a number of management studies and research efforts related to scheduling of examinations in radiology departments. Most of the articles that concentrated directly on scheduling methods identified staffing concerns as the primary impetus for the study.[2] Concern for patient waiting time, facility constraints and the impact of patient flow problems on the nursing staff are other issues that prompted work in this area.[3]

Studies to measure the productivity of a radiology department because of high personnel costs, complaints about waiting time and requests to expand facilities all touched on the need for a scheduling system to control the flow of patients.[4] Articles devoted to the analysis and control of patient waiting time also covered some aspects of scheduling methods.[5] One author's description of the objective of a patient scheduling system illustrates why scheduling issues are frequently addressed in radiology management studies: "An

adequate patient scheduling system in a radiology department should minimize patient waiting time while maximizing use of personnel, equipment, and facilities."[6]

Radiology departments suffer from a chronic problem of uneven workload during the day. Morning hours are busy, but equipment and personnel are often idle later in the day. Scheduling systems are implemented in an attempt to even out the flow of patients. Some authors insist that all examinations, except emergencies, should be scheduled.[7] A computer system can greatly enhance efforts to schedule all examinations.[8] Others cite large numbers of outpatient examinations and inadequate communication systems as barriers to scheduling more than a small portion of the examinations.[9]

The literature review yielded examples of industrial engineering and operations research techniques employed in the analysis of radiology departments. Work sampling, time records (logs), standard times and time studies are work measurement techniques used to determine the length of time required to perform examinations.[10] Data on patient waiting time have been analyzed with simulation techniques and regression analysis.[11] An article that was located after the proposal for this study had been written discussed the use of linear programming to maximize the contribution margin of an Ambulatory Diagnostic Center through case mix management.[12]

Although some articles referred to queuing theory, the actual use of queuing theory models and techniques to analyze

service capacity and patient waiting times was conspicuously absent from the literature. Queuing theory is used to study the functions of service systems.[13] Queuing models quantify such aspects of a service system as: (1) the average time a customer waits for service, (2) the average number of customers waiting in line, and (3) the probability that the service facility will be idle.[14] A problem with queuing theory is that the models become very complex when customer arrival patterns, queue discipline, service times and service configurations do not satisfy certain conditions.[15] This might explain why applications of queuing models to radiology departments were not found in the literature. Simulation techniques may be useful when the complexity of the service system precludes the use of queuing theory models.[16]

RESEARCH METHODOLOGY

OBJECTIVE 1: The current method of scheduling radiological examinations will be analyzed by examining documents such as Standing Operating Procedures and MEDDAC Regulations, and by observing the operation of the department. The analysis will determine the following:

1. Examinations that can be performed in each examination room

2. Examination rooms and time periods that are normally reserved for certain examinations

3. Types of patients (inpatient versus outpatient) and/or examinations that are normally scheduled by specific appointment times

4. Number of minutes each room is scheduled to be available for service on a daily basis

5. Number of minutes historically allotted in the schedule for various procedures

OBJECTIVE 2: An analysis of the Radiology Department operation will be conducted using the Radiology Daily Register (MACH Form 252), the Radiology Daily Procedure Schedule (MACH Form 220), and the Patient Control Card (MACH Form 51). Examples of these forms are provided as Appendixes A-C. In addition to the information normally recorded on the above forms, the following data will be recorded for each examination:

1. Time patient arrived at the radiology department

2. Time patient entered examination room

3. Time patient departed examination room

The patient arrival time will be recorded on the Radiology Daily Register by the receptionist. The times the patient entered and departed the examination room will be recorded on the Patient Control Cards by the radiology technicians. Data will be collected over a four-week period.

The data collected will allow the calculation or description of the following parameters concerning the operation of the department:

1. The average service time for each type of examination

2. The distribution of scheduled and unscheduled patient arrivals for each hour of the day

3. The average patient waiting time experienced by patients arriving during each hour of the day

4. Examination room utilization rates (in minutes used per day)

5. The number of radiological examinations requested by the various clinics

OBJECTIVE 3: The radiological workload expected during the EMU project will be estimated based on historical data and any expected major changes in the demand for radiological examinations. Workload data will be obtained from the Radiology Department's monthly workload report and the Patient Administration Division's monthly report on examinations ordered under Supplemental Care funds. The estimate will reflect the expected number of requests for each type of examination during the EMU project.

OBJECTIVE 4: Various constraints will affect the service capabilities and patient scheduling methods of the Radiology Department during the EMU project. The following are examples of such constraints:

1. Amount of time available in each of the examination rooms (service capacity). The hours of operation, staffing

schedules, expected equipment down time (to be obtained from an inspection of maintenance and repair records), and the amount of scheduled nonproductive time (e.g. committee meetings) all impact on the minutes available.

2. Specific examinations that must be done in-house. The desires of the Radiology Department or the medical staff might dictate that certain examinations cannot be shifted to another hospital.

3. Equipment capabilities. Certain examinations can only be done in certain rooms due to equipment capabilities.

4. The maximum acceptable average waiting time that patients are expected to experience during the EMU. Average patient waiting times for each hour of the day were determined under Objective 2. The Chief of the Radiology Department will consider this information in determining a maximum acceptable expected average waiting time for patients arriving during a one-hour period (Criterion 1).

OBJECTIVE 5: After conducting a literature search and considering the information obtained above, alternate scheduling methods will be identified. Aspects of the scheduling method that might be changed include:

1. Alteration of the time allotted for various examinations

2. Alteration of the number and/or type of examinations that are scheduled

3. Alteration of one or more constraints associated with a given scheduling method (i.e. changes in staffing schedules or hours of operation could affect the amount of time available in an examination room)

OBJECTIVE 6: Data collected under previous Objectives will be used to estimate the longest average waiting times expected during the EMU for patients arriving within a one hour period, given an alternate scheduling method.

1. The number of unscheduled patient arrivals expected for each hour of the day will be estimated by applying the hourly distribution of unscheduled patient arrivals (obtained under Objective 2) to the expected workload (obtained under Objective 3). The number of arrivals scheduled hourly under the alternate scheduling method will then be added to obtain the total number of expected patient arrivals for each hour.

2. The expected number of hourly patient arrivals and service capacity during the EMU will be weighed against the hourly number of patient arrivals and service capacity observed during the data collection period to arrive at an estimate of the longest average waiting times expected duing the EMU.

OBJECTIVE 7: For the alternate scheduling methods with their particular constraints, the following relationship exists:

Examinations done at MACH	+	Examinations done at other hospitals	=	Total projected workload

The actual objective is to minimize the expenditure of Supplemental Care funds on examinations done at other hospitals, so the objective function would be:

$$\text{Minimize: } \sum \left(\begin{array}{c}\text{cost of the}\\ \text{examination}\end{array}\right) \left(\begin{array}{c}\text{number of each type}\\ \text{of examination done}\\ \text{at other hospitals}\end{array}\right)$$

The constraints associated with a particular scheduling method are most easily expressed in terms of examinations that are done at MACH. To simplify the formulation of the linear programming problem, the minimization objective function involving examinations done at other hospitals can be converted to a maximization of the "payoff" associated with examinations that are done at MACH. If another hospital charges MACH $50 for doing a procedure, MACH saves $50 in Supplemental Care funds (the payoff) if it can do the examination in-house. The maximization function would be expressed as:

$$\text{Maximize: } \sum \left(\begin{array}{c}\text{cost of the}\\ \text{examination}\end{array}\right) \left(\begin{array}{c}\text{number of each type}\\ \text{of examination}\\ \text{scheduled at MACH}\end{array}\right)$$

To illustrate the use of linear programming to maximize the payoff of a scheduling method, a hypothetical scenario involving a limited number of examinations and constraints is outlined below:

Examination 1 must be done in room 1 or 2.

Examination 2 can be done in any room.

Examination 3 must be done in room 2 or 3.

Examination 4 can be done in any room.

Examination	Weighted cost	Minutes required for the procedure
1	$100	45
2	$50	30
3	$10	15
4	$5	10

Room 2 is temporarily closed for the EMU project. The Radiology Department decided that all examination 4's should be done in-house.

Let X_{ij} = the number of ith examinations done at MACH in the jth room during one month.

Objective function:

Maximize: $\$100X_{11} + \$50X_{21} + \$50X_{23} + \$10X_{33} + \$5X_{41} + \$5X_{43}$

Subject to:

$45X_{11} + 30X_{21} + 10X_{41} \leq$ minutes available in Rm #1 during one month

$30X_{23} + 15X_{33} + 10X_{43} \leq$ minutes available in Rm #3 during one month

$X_{41} + X_{43} \geq$ number of examination 4's projected for one month

The values obtained for the X_{ijs} will be compared to the projected workload to identify the type and number of examinations that must be referred to other hospitals, and the cost of shifting the examinations to the other hospitals will be calculated.

Although the EMU plan calls for three different combinations of examination rooms to be used during the renovation of the Radiology Department, only two linear programming models will be constructed. Since the General Electric and Picker machines have the same capabilities, the model constructed for the period when the General Electric machine is unavailable will also apply when the Picker machine is unavailable.

FOOTNOTES

[1]Elwood A. Buffa, Operations Management: The Management of Productive Systems (New York: John Wiley and Sons, Inc., 1976), pp. 301, 328.

[2]See Kenneth R. Ferron, Patricia A. Burke, and Daniel J. O'Connor, Jr., "Radiology Services' Study Improves Productivity, Care," Hospital Progress 63 (June 1982):50; Howard M. Blanken, Geoffrey T. Fromme, and Robert B. Toffler, "Patient Scheduling System Improves Productivity," Hospitals 55 (16 April 1981):71-72; and Karl E. Hansen and Larry R. Snider, "Scheduling System Shows Way to Expand," The Modern Hospital 102 (April 1964):110.

[3]See Dov Kanon, "Scheduling System for X-Rays Prevents Overtaxing of Facilities," Hospitals 41 (1 January 1967):87.

[4]See Tali Conine and Debra Aders, "Trim Costs with Two Management Tools," Hospital Financial Management 34 (September 1980):28; Robert B. Conrad et al., "Utilization Study Saved Hospital From Needless Expansion of Radiology Facility," Hospital Financial Management 27 (September 1973: 40-48; and Nancy H. Hill and Cengiz Tanverdi, "Radiology Department Study Leads to Improved Productivity," Hospitals 55 (16 April 1981):68-69.

[5]See R.G. Joat et al., "A Computer System to Monitor Radiology Department Activity: A Management Tool to Improve Patient Care," Radiology 145 (November 1982):347-50; and James T. Rhea and Robert P. Germaine, "The Relationship of Patient Waiting Time to Capacity and Utilization in Emergency Room Radiology," Radiology 130 (March 1979):637-41.

[6]Dickenson, p. 225.

[7]Hansen and Snider, p. 112; and Dickenson, p.225.

[8]Ronald L. Arenson and Jack W. London, "Comprehensive Analysis of a Radiology Operations Management Computer System," Radiology 133 (November 1979):356.

[9]Blanken, Fromme, and Toffler, p. 71.

[10]James K. McNally, "What Work Measurement Can Accomplish in Radiology," Hospital Financial Management 26 (September 1972):27-34.

[11]Conrad et al., pp. 46-48.

[12]Jack E. McDaniel, "Two Techniques for Alternatives Analysis," Radiology Management 6 (March 1984):13-15.

[13]Elwood A. Buffa, Operations Management: The Management of Productive Systems (New York: John Wiley and Sons, Inc., 1976), pp. 301-339.

[14]Richard A. Johnson, Fremont E. Kast, and James E. Rosenzweig. The Theory and Management of Systems (New York: McGraw-Hill Book Company, 1982), p. 211.

[15]Roger D. Eck, Operations Research for Business (Belmont, California: Wadsworth Publishing Company, 1976), p. 548.

[16]Richard I. Levin, Charles A. Kirkpatrick, and David S. Rubin. Quantitative Approaches to Management (New York: McGraw-Hill Book Company, 1982), p. 586.

II. DISCUSSION

CURRENT METHOD OF SCHEDULING EXAMINATIONS

The Radiology Department's hours of operation are 0730-1600 Monday through Friday. Radiology technicians are on call to perform emergency procedures outside the normal hours of operation. The Department currently has only one operational examination room, so the total examination room time routinely available is 8.5 hours per day. The room is equipped with a General Electric x-ray machine that is capable of performing general x-rays, mammograms, fluoroscopic and special radiological examinations.

Prior to October 1985, when two examinations rooms were operational, the Radiology Department scheduled patients for mammograms, fluoroscopic and special procedures. As illustrated by the Radiology Daily Procedure Schedule (MACH Form 220) at Appendix B, examinations were scheduled in 45-minute time periods from 0730-1115 and 1300-1600. Gall bladder (OCG) studies, intravenous pyelograms (IVP's), barium enemas (BE's), upper gastrointestinal (UGI) studies and other fluoroscopic or special examinations that require the patient to fast were scheduled in the morning. Studies that do not require the patient to fast--such as arthrograms, venograms, tomograms and mammograms--were scheduled in the afternoon.

The current method of scheduling examinations has evolved

from attempts by the Radiology Department to deal with the constraints of a single operational examination room. Outpatient fluoroscopic and special procedures are scheduled by specific appointment times. General x-ray examinations for outpatients are performed on a "first come, first served" basis. Examinations for inpatients are fit into the work flow on an "on call" basis, which means the Radiology Department notifies the ward to deliver the patient when the room is available to do the examination. All mammograms are sent out to other hospitals and paid for with Supplemental Care funds.

Fluoroscopic and special procedures for outpatients are typically scheduled for three 45-minute time periods beginning at 0900, 0945 and 1300 for each day of the week except Thursday. No fluoroscopic or special examinations are scheduled on Thursdays, because MACH has contracted for the services of a mobile computerized tomography (CT) unit on Thursday afternoons. The MACH radiologist must be available to read CT scans in the mobile unit by noon, so he cannot risk being tied up with a backlog of fluoroscopic or special procedures on that day. The radiologist also attends a continuing education program on the last Friday of each month, so patients are not appointed at 1300 on that day.

Appointments for outpatient fluoroscopic and special procedures are typically booked over a month in advance. The physician writes the maximum acceptable waiting time for an appointment on the request for the examination. If the

Radiology Department has an appointment time available within that time period, the patient is scheduled for the examination. If an appointment is not available, the patient is scheduled for the examination at another facility, and MACH pays for the examination with Supplemental Care funds. No scheduling priority is given for specific types of examinations or for a particular physician. The maximum acceptable waiting time noted on the request is the only factor used to decide whether a given fluoroscopic or special procedure is done at MACH or at some other facility.

Mammograms are currently sent to St. John Hospital in Leavenworth and to Kansas University Medical Center in Kansas City, Kansas. All other examinations are sent to the Veterans Administration Medical Center in Leavenworth.

ANALYSIS OF CURRENT OPERATION

Data concerning 751 examinations performed during the Radiology Department's normal operating hours were collected during the four-week study period of 21 March-17 April 1986. The receptionist recorded the time each patient arrived at the department on the Radiology Daily Register (MACH Form 252). The radiology technician recorded the times that each patient entered and departed the examination room on the Patient Control Card (MACH Form 51). Seven data elements concerning each examination were then gleaned from these forms and entered into

a computerized data base. A printout of the data base is provided at Appendix D.

The first three data elements are the day that the examination was performed, the clinic or ward that requested the examination, and the type of examination performed. Legends or explanations for the abbreviations used for these data elements are provided in Appendix D.

The fourth data element is the hour of the day that the patient arrived at the radiology department. Patients arriving from 0730-0829 are identified by "0800" as the arrival hour. Patients arriving from 0830-0929 are identified by "0900", and so on. Since the department closes at 1600, the "1600" arrival hour only applies to patients arriving in the 1530-1600 time period.

The fifth data element is the waiting time experienced by the patient. The waiting time is defined as the number of minutes from the time the patient arrived at the Radiology Department until the patient entered the examination room.

The sixth data element is the service time for the examination. The service time is defined as the number of minutes that the patient actually occupied the examination room.

The seventh data element is the transition time between examinations. The transition time is the number of minutes elapsed from the time one patient departs the examination room until the next patient, who has been waiting, enters the examination room. Transition time is counted only when there is

a patient waiting for an examination. When there is no patient waiting for an examination and the room is empty, it is considered idle time. Since idle time occured so infrequently, it was tabulated separately from the data base.

The number of examinations, total service time and average service time for each type of examination performed during the study period are listed in Table 1. The overall average service time for general x-ray examinations is 5.7 minutes, compared to a 41.5 minute average service time for fluoroscopic and special procedures. Although the 52 fluoroscopic and special procedures represent only 7 percent of the examinations performed, they account for 35 percent of the total service time.

The average service times for three types of examinations merit comment. The average service time of 12.5 minutes for an abdominal series examination is skewed by an examination involving a trauma patient that took 60 minutes to complete. The other three abdominal series examinations had an average service time of only five minutes. The multiple general x-ray examination refers to patients who underwent more than one general x-ray procedure, which accounts for the relatively long average service time for that type of examination. The radiology technicians thought that the 35 minute service time observed for the arthrogram is less than the true average. Future calculations that involve arthrograms will use 40 minutes as the average service time.

TABLE 1

EXAMINATION SERVICE TIMES
(In Minutes)

Type of Examination	Number of Examinations	Total Service Time	Average Service Time
General X-Rays:			
Chest/Rib	202	663	3.3
Extremeties	347	1641	4.7
Head/Sinus	31	273	8.8
Spine	89	891	10.0
Kidneys/Ureters/Bladder	4	24	6.0
Abdominal Series	4	75	12.5
Multiple	22	427	19.4
Total	699	3994	5.7
Fluoroscopic and Special:			
Upper Gastrointestinal	10	283	28.3
Barium Enema	14	602	43.0
Arthrogram	1	35	35.0
Intravenous Pyelogram	16	651	40.7
Tomogram	3	181	60.3
Xerogram	1	60	60.0
Others	7	345	49.3
Total	52	2157	41.5

In addition to the service time required for each examination, the number of examinations completed within a given time depends on the transition time between examinations. Excessive transition times could result from delays caused by incomplete examination requests, patient flow problems, equipment adjustments required for certain procedures, or frequent minor equipment malfunctions. The average transition time observed during the study period was 4.1 minutes.

The time required to complete an examination is actually the sum of the service time and the transition time. By adding

The 4.1 minute average transition time to the overall average service times listed in Table 1, the average completion time for general x-ray examinations is 9.8 minutes, and the average completion time for fluoroscopic and special examinations is 45.6 minutes.

The distribution of patient arrivals for each hour of the day during the study period is shown in Table 2. Almost 40 percent of the patients arrived during the first two hours of the day. Sixty-five percent of the patients undergoing fluoroscopic or special examinations arrived during the first three hours of the day. The scheduled arrivals included 15 patients who were scheduled for 0900, 14 patients who were scheduled for 0945 and six patients who were scheduled for 1300. The Radiology Department had actually scheduled 41 patients for fluoroscopic and special examinations during the study period, but six patients (15 percent) cancelled for various reasons. Unscheduled arrivals for fluoroscopic and special examinations include the inpatient examinations, which were performed "on call", and emergencies.

TABLE 2

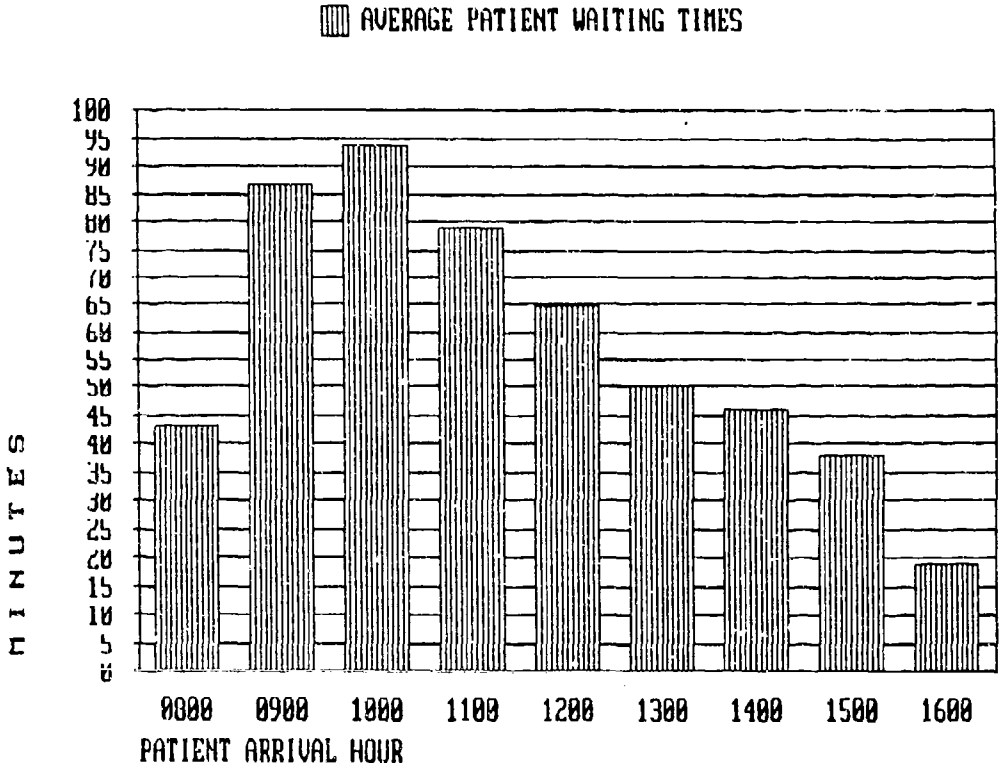
DISTRIBUTION OF PATIENT ARRIVALS
(Numbers and Percentages)

Arrival Hour	General X-Rays (#	%)	Sched. F&S[a] (#	%)	Unsched. F&S[b] (#	%)	Hourly Total (#	%)
0800	177	25.3	7	20.0	1	5.8	185	24.6
0900	99	14.2	12	34.3	3	17.6	114	15.2
1000	86	12.3	10	28.5	1	5.9	97	12.9
1100	77	11.0	--	----	2	11.8	79	10.5
1200	57	8.2	--	----	4	23.5	61	8.1
1300	63	9.0	4	11.4	1	5.9	68	9.1
1400	58	8.3	2	5.7	3	17.6	63	8.4
1500	60	8.6	--	----	2	11.8	62	8.3
1600	22	3.1	--	----	-	----	22	2.9
Total	699		35		17		751	

[a]Sched. F&S denotes scheduled fluoroscopic and special examinations.
[b]Unsched. F&S denotes unscheduled fluoroscopic and special examinations.

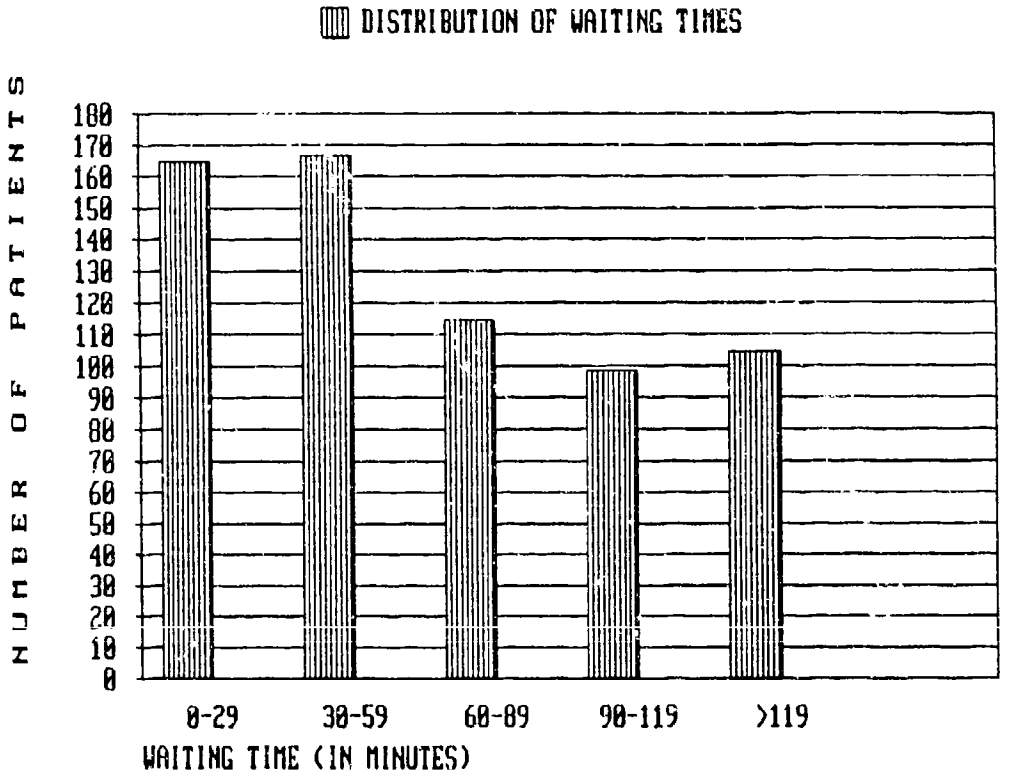
Figure 1 depicts the average patient waiting time experienced by patients arriving during each hour of the day. The combination of the long service times required for fluoroscopic and special examinations and the large numbers of patients arriving early in the day results in very long waiting times during the morning hours. Patients arriving during the 1000 arrival hour experienced the longest average waiting time of 94 minutes. The overall average waiting time for the 751 patients included in the study period was 62 minutes.

FIGURE 1



The distribution of waiting times was analyzed to see if a few patients with very long waiting times had distorted the average waiting times. The distribution of waiting times is displayed in Figure 2. Since 319 patients (42.5 percent of all patients) experienced waiting times of one hour or more, it was concluded that the average waiting times were not distorted by a few patients with excessive waiting times.

FIGURE 2



The status of the examination room at any given moment falls into one of four categories. When a patient is in the room, it is identified as service time. The time between examinations is transition time. Idle time occurs when the room is empty, and no patients are waiting. The room could also be down for maintenance or repair. The utilization of the examination room during the study period is summarized in Table 3. The combination of the service and transition times results in a 90 percent utilization rate for the examination room.

TABLE 3

EXAMINATION ROOM UTILIZATION
STUDY PERIOD

Status	Minutes	Percent of Total Time
Service time	6151	60
Transition time	3085	30
Idle time	626	6
Repair and maintenance	413	4

Requests for radiological examinations came from 20 clinics, wards and services during the study period. The number of examinations requested by each is displayed in Table 4. There were 717 outpatient examinations and only 34 inpatient examinations.

TABLE 4

EXAMINATION REQUESTS BY SERVICE
STUDY PERIOD

Service	Number	Service	Number
General Outpatient Clinic	194	Physical Therapy	5
Orthopedics	160	Allergy Clinic	2
Family Practice	87	Dental Clinic	2
Medical Exam Clinic	75	Eyes, Ears, Nose	
Emergency Room	72	and Throat Clinic	1
Internal Medicine	48	Mental Health Clinic	1
Pediatrics	30	Ward 3B	23
U.S. Disciplinary Barracks	15	Ward 2C	7
Obstetrics/Gynecology	10	Ward 2B	3
General Surgery	9	U.S. Disciplinary	
Community Health Clinic	6	Barracks Ward	1

ESTIMATE OF WORKLOAD DURING THE EMU

The renovation of the Radiology Department under the EMU

project is scheduled for August 1986 through April 1987. No major changes are expected in the demand for radiological examinations during this period as compared to the prior year. The estimates of the expected workload are based on workload records from the Radiology Department and the Patient Administration Division's monthly report on referrals of Supplemental Care for August 1985 through April 1986. The estimates for each three-month period during the ENU project are contained in Appendix E.

The workload estimates could not simply be extracted from the Radiology Department's monthly workload reports, because the department reports workload differently than the way the workload data was collected during the study period. For example, three different views of the spine for a single patient are counted as three examinations by the Radiology Department, while they would have been counted as a single examination during the study. The summary reports also contain workload performed outside the normal hours of operation (i.e. nights and weekends). The study period only covered workload performed during normal operating hours Monday through Friday during a four-week period. To eliminate such discrepancies, workload data from the Radiology Daily Register (MACH Form 252) were used in making the estimates. The estimates reflect the average number of requests for examinations that are expected during normal operating hours for a four-week period.

CONSTRAINTS DURING THE EMU

One of the constraints on the operation of the Radiology Department during the EMU concerns the x-ray equipment that will be available. The General Electric will be the only machine available during the first three-month period. It can perform general x-rays, mammograms, fluoroscopic and special procedures. The Phillips and Picker machines will both be available during the second three-month period. The Phillips machine can perform general x-rays, mammograms, intravenous pyelograms, tomograms and xerograms; but no fluoroscopies. The Picker machine has essentially the same capabilities as the General Electric machine. The Phillips and General Electric machines will be available during the last three months of the EMU project.

With only one machine in operation, the amount of examination room time available will be minimal during the first three months of the project. The 170 hours of examination room time that are ostensibly available during normal operating hours in a four-week period are reduced by certain factors. A review of Maintenance Requests (DA Form 2407) for the General Electric machine revealed that it was down for repairs or maintenance an average of 14 hours per four-week period (8.2 percent of the time). probably invalid statistically

The contracted mobile computerized tomography service and the continuing education programs routinely take the radiologist out of the department for four hours each Thursday afternoon and

four hours one Friday afternoon a month. Although the examination rooms are still available for general x-ray examinations, fluoroscopic and special procedures cannot be done because the radiologist is not available. These known absences would be taken into account in determining the number of appointments available for a given scheduling system.

Whenever the radiologist is unavailable because of leave, temporary duty, illness, etc., the number of appointments is further reduced. Given the scheduling method in effect during the study period, appointments for 47 fluoroscopic and special procedures would supposedly have been available, but various absences by the radiologist reduced the number available to 41. As discussed earlier, six of the 41 scheduled patients cancelled their appointments, so only 35 (75 percent) of the 47 appointments that would supposedly have been available actually resulted in examinations being performed.

The Radiology Department did not identify any specific procedures that absolutely must be done in-house. A review of the reports on referrals of supplemental care revealed that essentially all types of examinations have been referred to other facilities at some time. The department naturally wants to avoid sending any inpatients or patients requiring only routine x-ray examinations to other hospitals.

As illustrated earlier, the patient waiting time for x-ray examinations at MACH is quite long. An average waiting time of 94 minutes for patients arriving from 0930-1029 was deemed to be

unacceptable. Radiology Department personnel consider 60 minutes to be the maximum acceptable expected average waiting time for patients arriving during any one-hour period if only one x-ray machine is available. The maximum acceptable expected waiting time is 30 minutes when two machines are available.

ALTERNATE SCHEDULING METHODS

The opposing objectives of maximizing the number of radiological examinations performed in-house while keeping expected patient waiting times below the maximum acceptable level were the prime considerations in developing alternate scheduling methods. As discussed previously, the long patient waiting times are caused by large numbers of patients arriving early in the day when fluoroscopic and special procedures are performed.

The waiting times experienced by patients arriving within a given one-hour period depend, in part, on the time required to complete the examinations for those patients and the time required to complete the examinations for any patients who arrived during previous hours and are still waiting for examinations. Table 5 displays the average time required to complete the examinations for patients arriving during each hour of the day during the study period, and the average waiting times they experienced.

TABLE 5

AVERAGE EXAMINATION COMPLETION AND PATIENT WAITING TIMES
STUDY PERIOD
(In Minutes)

Arrival Hour	Average Daily Arrivals		Average Time Required to Complete Examinations			Cumulative Variance from Service Capacity	Average Patient Waiting Time
	Gen[a]	F&S[b]	Gen	F&S	Total		
0800	8.85	0.40	87	18	105	+45	43
0900	4.95	0.75	49	34	83	+68	87
1000	4.30	0.55	42	25	67	+75	94
1100	3.85	0.10	38	5	43	+58	79
1200	2.85	0.20	28	9	37	+35	65
1300	3.15	0.25	31	11	42	+17	50
1400	2.90	0.25	28	11	39	-4	46
1500	3.00	0.10	29	5	34	-30	38
1600	1.10	--	11	--	11	-49	19

[a]Gen denotes general x-rays.
[b]F&S denotes fluoroscopic and special examinations.

The average daily arrivals for general x-ray and fluoroscopic and special examinations were determined by dividing the number of arrivals in Table 2 by 20, since each four-week period contained 20 days. The average times required to complete the examinations were calculated by multiplying the average daily arrivals for general x-ray and fluoroscopic and special examinations by their average completion times of 9.8 and 45.6 minutes respectively. The cumulative variance from the service capacity for each arrival hour was calculated by subtracting 60 from the total average time required to complete the examinations for that hour, and adding the difference to the cumulative variance from the previous hour. A cumulative

variance greater than zero indicates that, on the average, the workload exceeds the service capacity of the department and a backlog of patients waiting for examinations exists.

The average time required to complete the examinations exceeded 60 minutes for each of the first three hours of the day, with the cumulative variance from the service capacity reaching 75 minutes. The patients arriving from 0930-1029 experienced the longest average waiting time because they had to wait for the backlog of patients from the first two hours of operation to be examined. The average times required to complete the examinations were less than 60 minutes for the remaining hours of the day, and the average patient waiting times continued to decrease during those hours as the backlog of patients diminished. The department did not "catch up" with the backlog of patients until the cumulative variance from the service capacity turned negative during the 1400 arrival hour. Therefore, on the average, the excess workload of the first three hours of operation affected the waiting times for patients arriving up through the 1300 arrival hour. A change in the scheduling method that would change the required examination completion time for any of the first six hours of the day would affect the average waiting times for patients arriving during subsequent hours until 1330.

A scheduling method that shifts patient arrivals into the afternoon hours would reduce the long average waiting times in the morning hours, but shifting the pattern of patient arrivals

would be very difficult to accomplish. Most of the fluoroscopic and special procedures require the patient to fast prior to the examination. Shifting these examinations to the afternoon would increase patient discomfort. General x-ray examinations are not scheduled, so the Radiology Department cannot control the arrival pattern of these patients. It is not feasible to schedule these examinations because of their short duration, their acute nature, and the difficulties that would be encountered in coordinating appointments with a large number of outpatients and requesting physicians. Other authors have reached the same conclusion regarding the feasibility of scheduling general x-ray examinations.[1]

The only apparent method to keep expected patient waiting times below the 60-minute maximum acceptable level with a single operational x-ray machine is to reduce the number of fluoroscopic and special examinations scheduled to be performed in-house. Two alternate scheduling methods are proposed for the first three-month period of the EMU project.

Alternate Scheduling Method #1 is to schedule one fluoroscopic or special procedure at 0900 and one at 1300 daily (as compared to the current method of scheduling such examinations at 0900, 0945 and 1300). The 0900 appointment should be reserved for examinations that require the patient to fast. The 1300 appointment will be used for examinations that do not require the patient to fast. No examinations will be scheduled on Thursdays because of the mobile CT service, and the

1300 appointment will not be scheduled on the day that the radiologist attends the continuing medical education program.

Alternate Scheduling Method #2 is to schedule only one fluoroscopic or special examination at 1300 with no examinations scheduled in the mornings. The exceptions noted above would be made for the mobile CT service and the continuing medical education program.

Unscheduled fluoroscopic and special examinations (i.e. inpatients and outpatient emergencies) will still be performed in-house and all mammograms will still be sent to other facilities under both alternate scheduling methods.

Two x-ray machines will be available during the second and third three-month periods of the EMU. The Phillips and Picker rooms will be operational during the second period and the Phillips and General Electric rooms during the third period. The General Electric and Picker machines have the same capabilities, so the same scheduling alternatives would apply to both time periods. In the subsequent discussion of the alternate scheduling methods, all references to the Picker machine used in the second period would also apply to the use of the General Electric machine in the third period. Two alternate scheduling methods are proposed for the second and third three-month periods of the EMU project.

Alternate Scheduling Method #3 is to perform all general x-ray examinations in the Phillips room. The relatively few tomograms and xerograms (only three per month are estimated)

will also be scheduled for the Phillips machine at 1300. Fluoroscopic and special examinations that require the patient to fast will be scheduled for the Picker room from 0730-1115 daily. Mammograms, arthrograms and venograms will also be scheduled for the Picker room from 0730-1115 daily, and from 1300-1500 each afternoon, except on Thursdays and one Friday each month. The mix of procedures that will be appointed if the service capacity of the department is not sufficient to do all the expected examinations will subsequently be determined with a linear programming technique. The Picker machine will also be used for any unscheduled fluoroscopic and special examinations occurring throughout the day.

Alternate Scheduling Method #4 is to devote both machines to general x-ray examinations from 0730-0830 daily. After 0830, all general x-ray examinations will be performed in the Phillips room. The tomograms and xerograms will also be done in the Phillips room. Fluoroscopic and special examinations that require the patient to fast will be scheduled for the Picker room from 0830-1130 daily. Mammograms, arthrograms and venograms will also be scheduled from 0830-1130 daily, and as outlined above for the afternoon hours. The previous statements regarding the mix of procedures and unscheduled examinations also apply to this scheduling method.

ESTIMATE OF EXPECTED AVERAGE WAITING TIMES

The first criterion for evaluating the alternate scheduling methods concerns the expected average waiting times for patients arriving within a one-hour period. The maximum acceptable expected average waiting times are 60 minutes when only one examination room is available and 30 minutes when two examination rooms are available.

The expected average waiting times during the EMU project for each alternate scheduling method are estimated as follows:

1. The expected hourly distribution of patient arrivals, given the particular scheduling method, is determined.

2. The expected average times required to complete the examinations for patients arriving during each hour of the day and the cumulative variances from the service capacity are calculated. The department is expected to experience, on the average, a continuous backlog of patients during consecutive hours of operation that the cumulative variance remains positive. The break-even point is reached when the cumulative variance from the service capacity turns negative. If the cumulative variance from the service capacity remains negative, the patient waiting times for arrival hours subsequent to the break-even point will not be influenced by a backlog of patients and are expected to average less than 30 minutes.

3. The differences between the expected average times required to complete the examinations during the EMU project and

the average time required to complete the examinations during the study period are calculated.

4. The cumulative differences in the time required to complete the examinations are used to adjust the waiting times observed during the study period to estimate the expected average waiting times during the EMU project. The adjustment of waiting times applies only to the consecutive hours of the day until the break-even point is reached.

Alternate Scheduling Method #1

As outlined previously, Alternate Scheduling Method #1 for the first three-month period of the EMU project would schedule fluoroscopies and special examinations at 0900 and 1300 daily, with some exceptions. The expected hourly distribution of patient arrivals for this scheduling method is shown in Table 6.

TABLE 6

EXPECTED DISTRIBUTION OF PATIENT ARRIVALS
ALTERNATE SCHEDULING METHOD #1

Arrival Hour	General X-Rays	Sched. F&S	Unsched. F&S	Total F&S
0800	187	7	1	8
0900	105	8	3	11
1000	91	-	1	1
1100	81	-	2	2
1200	61	-	4	4
1300	66	4	1	5
1400	61	2	3	5
1500	63	-	2	2
1600	23	-	-	-
Total	738	21	17	38

The expected distribution of general x-rays is based on the assumption that the hourly distribution of unscheduled patient arrivals during the EMU will be the same as that observed in the study period. The expected average of 738 general x-rays per four-week period for August-October 1986 (from Appendix E) was multiplied by the hourly percentage distribution of general x-rays from Table 2. The number and distribution of unscheduled fluoroscopic and special examinations (inpatients and outpatient emergencies) are assumed to remain the same as that observed during the study period. The elimination of the 0945 appointment slot in this scheduling method is reflected in the number and distribution of the scheduled fluoroscopic and special examinations by the elimination of 14 patient arrivals corresponding to those observed in the study period (see discussion concerning Table 2).

Table 7 shows the expected average times required to complete the examinations for patients arriving during each hour of the day and the cumulative variance from the service capacity. The calculation methods used and the setup of Table 7 are essentially the same as for Table 5. Since the cumulative variance from the service capacity turned negative during the 1400 arrival hour, the adjustments to waiting times (see Tables 9 and 10) will end with the 1300 arrival hour, and the waiting times during subsequent hours are expected to average less than 30 minutes.

TABLE 7

EXPECTED AVERAGE EXAMINATION COMPLETION TIMES
AND CUMULATIVE VARIANCE FROM SERVICE CAPACITY
ALTERNATE SCHEDULING METHOD #1

Arrival Hour	Average Daily Arrivals		Average Time Required to Complete Examinations (In minutes)			Cumulative Variance from Service Capacity (In minutes)
	Gen.	F&S	Gen.	F&S	Total	
0800	9.35	0.40	92	18	110	+50
0900	5.25	0.55	51	25	76	+66
1000	4.55	0.05	45	2	47	+53
1100	4.05	0.10	40	5	45	+38
1200	3.05	0.20	30	9	39	+17
1300	3.30	0.25	32	11	43	0
1400	3.05	0.25	30	11	41	-19
1500	3.15	0.10	31	5	36	-43
1600	1.15	--	11	--	11	-62

Table 8 depicts the differences between the study period and Alternate Scheduling Method #1 in the average times required to complete the examinations for patients arriving during each hour of the day up to the break-even point.

TABLE 8

DIFFERENCES IN AVERAGE EXAMINATION COMPLETION TIMES REQUIRED
ALTERNATE SCHEDULING METHOD #1
(In Minutes)

Arrival Hour	Study Period (Observed)	Alternate Method #1 (Expected)	Difference	Cumulative Difference
0800	105	110	+5	+5
0900	83	76	-7	-2
1000	67	47	-20	-22
1100	43	45	+2	-20
1200	37	39	+2	-18
1300	42	43	+1	-17

Table 9 shows the estimates of the expected average waiting times associated with Alternate Scheduling Method #1 resulting from the adjustment of waiting times observed during the study period by the cumulative difference in the average examination completion times required. The expected average waiting times for the 0900 and 1000 arrival hours exceed the 60-minute maximum acceptable expected average waiting time.

TABLE 9

ESTIMATE OF EXPECTED AVERAGE WAITING TIMES
ALTERNATE SCHEDULING METHOD #1
(In Minutes)

Arrival Hour	Study Period Average Patient Waiting Time (Observed)	Cumulative Difference in Average Examination Completion Time (+ or -)	Expected Average Patient Waiting Time
0800	47	+5	52
0900	87	-2	85
1000	94	-22	72
1100	79	-20	59
1200	65	-18	47
1300	50	-17	33

ALTERNATE SCHEDULING METHOD #2

The estimate of the expected average waiting times for Alternate Scheduling Method #2 was calculated in the same manner as above and is shown in Appendix F in Tables 20-23. Tables 20-23 correspond directly to Tables 6-9 above. The longest expected average waiting time associated with Alternate Scheduling Method #2 is 51 minutes, which meets the 60-minute

criterion for the maximum acceptable waiting time.

Alternate Scheduling Method #3

The estimate of expected average waiting times for Alternate Scheduling Method #3 involves patient arrivals for two examination rooms. The expected distribution of patient arrivals for the Phillips room is shown in Table 10. The expected average of 656 general x-rays per four-week period for November 1986 through January 1987 (from Appendix E) was distributed according to the hourly distribution observed during the study period. The three scheduled fluoroscopic and special examinations represent the tomograms and xerograms.

TABLE 10

EXPECTED DISTRIBUTION OF PATIENT ARRIVALS
ALTERNATE SCHEDULING METHOD #3
(Phillips Room)

Arrival Hour	General X-Rays	Sched. F&S
0800	166	-
0900	93	-
1000	81	-
1100	72	-
1200	54	-
1300	59	3
1400	55	-
1500	56	-
1600	20	-
Total	656	3

The expected number of scheduled patient arrivals for the

Picker room, displayed in Table 11, is based on the observation during the study period that the number of scheduled examinations actually performed was only 75 percent of the number of appointments that would supposedly have been available under the scheduling method in effect. Alternate Scheduling Method #3 would supposedly provide one hundred 45-minute appointments from 0730-1115 and sixty 30-minute appointments (the radiology technicians estimate that mammograms take 30 minutes to complete) from 1300-1500 during a four-week period. The actual numbers of scheduled patient arrivals are expected to be 75 and 45 during the respective time periods. This calculation was not made for Alternate Scheduling Methods #1 and #2 because the expected patient arrivals for those methods were estimated by adjusting the numbers of actual patient arrivals observed during the study period. The number and distribution of unscheduled fluoroscopic and special examinations are expected to be the same as observed during the study period.

TABLE 11

EXPECTED DISTRIBUTION OF PATIENT ARRIVALS
ALTERNATE SCHEDULING METHOD #3
(Picker Room)

Arrival Hour	Sched. F&S	Unsched. F&S	Total F&S	Mammograms
0800	20	1	21	--
0900	20	3	23	--
1000	20	1	21	--
1100	15	2	17	--
1200	--	4	4	--
1300	--	1	1	15
1400	--	3	3	20
1500	--	2	2	10
1600	--	-	-	--
Total	75	17	92	45

The expected average examination completion times and the cumulative variance from the service capacity for the Phillips and Picker rooms are shown in Tables 12 and 13. The cumulative variance from the service capacity in the Picker room is constantly negative, so the waiting times experienced by patients examined in the room are expected to average less than 30 minutes throughout the day. The same is true for the Phillips room beginning with the 1000 arrival hour.

TABLE 12

EXPECTED AVERAGE EXAMINATION COMPLETION TIMES
AND CUMULATIVE VARIANCE FROM SERVICE CAPACITY
ALTERNATE SCHEDULING METHOD #3
(Phillips Room)

Arrival Hour	Average Daily Arrivals		Average time Required to Complete Examinations (In minutes)			Cumulative Variance from Service Capacity (In minutes)
	Gen.	F&S	Gen.	F&S	Total	
0800	8.30	--	81	--	81	+21
0900	4.65	--	46	--	46	+7
1000	4.05	--	40	--	40	-13
1100	3.60	--	35	--	35	-38
1200	2.70	--	26	--	26	-72
1300	2.95	0.15	29	10	39	-93
1400	2.75	--	27	--	27	-126
1500	2.80	--	27	--	27	-153
1600	1.00	--	10	--	10	-173

TABLE 13
EXPECTED AVERAGE EXAMINATION COMPLETION TIMES
AND CUMULATIVE VARIANCE FROM SERVICE CAPACITY
ALTERNATE SCHEDULING METHOD #3
(Picker Room)

Arrival Hour	Average Daily Arrivals		Average Time Required to Complete Examinations (In minutes)			Cumulative Variance from Service Capacity (In minutes)
	F&S	Mammo	F&S	Mammo	Total	
0800	1.05	--	48	--	48	-12
0900	1.15	--	52	--	52	-20
1000	1.05	--	48	--	48	-32
1100	0.85	--	39	--	39	-53
1200	0.20	--	9	--	9	-104
1300	0.05	0.75	2	23	25	-139
1400	0.15	1.10	7	33	37	-162
1500	0.10	0.50	5	15	20	-202
1600	--	--	--	--	--	-232

The differences between Alternate Scheduling Method #3 and

the study period in the average examination completion times required for the Phillips room are calculated in Table 14 and are used to calculate the expected average patient waiting times for the 0800 and 0900 arrival hours in Table 15. The 30-minute waiting time criterion is also met in the Phillips room under Alternate Scheduling Method #3.

TABLE 14

DIFFERENCES IN AVERAGE EXAMINATION COMPLETION TIMES REQUIRED
ALTERNATE SCHEDULING METHOD #3
(Phillips Room)
(In Minutes)

Arrival Hour	Study Period (Observed)	Alternate Method #1 (Expected)	Difference	Cumulative Difference
0800	105	81	-24	-24
0900	83	46	-37	-61

TABLE 15

ESTIMATE OF EXPECTED AVERAGE WAITING TIMES
ALTERNATE SCHEDULING METHOD #3
(Phillips Room)
(In Minutes)

Arrival Hour	Study Period Average Patient Waiting Time (Observed)	Cumulative Difference in Average Examination Completion Time (+ or -)	Expected Average Patient Waiting Time
0800	47	-24	23
0900	87	-61	26

Alternate Scheduling Method #4

Alternate Scheduling Method #4 would schedule fewer

patients for examinations than Alternate Scheduling Method #3. Since Alternate Scheduling Method #3 meets the 30-minute waiting time criterion for both examinations rooms, the same can be expected for Alternate Scheduling Method #4.

OPTIMAL MIX OF SCHEDULED EXAMINATIONS

The final step in determining the optimal method for scheduling radiological examinations during the EMU project is the use of linear programming to determine the mix of scheduled examinations to be done at MACH that will minimize the expenditure of Supplemental Care funds for examinations performed at other hospitals. However, the linear programming technique is not needed to determine the optimal mix of scheduled examinations for the first three-month period of the EMU project. Alternate Scheduling Method #2, which schedules one fluoroscopic or special examination per day at 1300, is the only scheduling method that meets the 60-minute maximum allowable average waiting time criterion. Fluoroscopic and special examinations that require the patient to fast should not be scheduled at 1300; so arthrograms, tomograms and venograms are the only procedures that can be scheduled under Alternate Scheduling Method #2. Only seven of these examinations are expected to be requested during each four-week period (Appendix E). All seven examinations would easily be accommodated in the schedule. The linear programming technique is not needed to

determine the optimal mix of scheduled examinations because the time availble is not a constraint.[2]

Alternate Scheduling Methods #3 and #4 meet the waiting time criterion for the second and third three-month periods of the EMU project. Two examination rooms will be available during these time periods, but the only scheduled examinations performed in the Phillips room will be a small number of tomograms and xerograms, so linear programming is not needed to determine an optimal mix of scheduled examinations for the room.

A linear programming model is now developed to determine the optimal mix of examinations to be scheduled for the Picker room during the second three-month period of the EMU project under Alternate Scheduling Method #3. The scheduling constraints that apply to the Picker room would also apply to the General Electric room during the final three months of the EMU project, so separate models will not be constructed for that time period.

As discussed in the introduction to this study, an objective function that maximizes the "payoff" of examinations scheduled to be done at MACH can be used in a linear programming model to minimize the expenditure of supplemental care funds for examinations sent out to other hospitals:

Maximize: Z=	cost of the examination	number of each type of examination scheduled at MACH

where Z is the dollar value of the payoff realized from the examinations scheduled at MACH, and the cost of the examination is the amount MACH would have to pay another hospital to do the examination.

The following variables are used to designate the number of each examination to be scheduled in the Picker room:

X1 = Upper gastrointestinal
X2 = Barium Enema
X3 = Barium Swallow
X4 = Gall Bladder
X5 = Small Bowel Follow-Through
X6 = Arthrogram
X7 = Venogram
X8 = Intravenous Pyelogram
X9 = Other Fluoroscopic and Special
X10 = Mammogram

The amounts charged by other hospitals for the above examinations were obtained from the Patient Administration Division. Using these charges, the objective function becomes:

Maximize: $Z = \$39X1 + \$80X2 + \$15X3 + \$33X4 + \$60X5 + \$120X6 + \$130X7 + \$110X8 + \$175X9 + \$60X10$

The model addresses three constraints: (1) the time available for scheduled examinations that must be performed in the morning, (2) the total time available for scheduled examinations, and (3) constraint inequalities that prevent the model from providing a quantity of an examination to be scheduled that exceeds the expected demand for that particular examination.

The constraint for the time available for scheduled examinations that must be performed in the morning is expressed

as:

$$32X1 + 47X2 + 15X3 + 20X4 + 60X5 + 0X6 + 0X7 + 45X8 + 53X9 + 0X10 \leq 4140 \text{ minutes}$$

The non-zero coefficients of the variables represent the average times required to complete the examinations. These times were calculated from observations made during the study period or were estimated by the radiology technicians if the particular examination was not performed during the study period. The coefficients for X6, X7 and X10 are zeros because arthrograms, venograms and mammograms do not require the patient to fast. Alternate Scheduling Method #3 calls for examinations to be scheduled from 0730 to 1115 daily. Taking into account the 8.2 percent downtime for maintenance and repairs that was noted in the review of the maintenance records, the 4140 minutes (69 hours) available for scheduled examinations that must be performed in the morning is calculated as follows:

$$(3.75 \text{ hours/day})(20) - (3.75)(20)(.082) = 69 \text{ hours per 4-week period}$$

The second constraint is the total time available to do scheduled examinations. This constraint is expressed as:

$$32X1 + 47X2 + 15X3 + 20X4 + 60X5 + 45X6 + 60X7 + 45X8 + 53X9 + 30X10 \leq 5790 \text{ minutes}$$

The coefficients representing the time required to complete

arthrograms, venograms and mammograms are now in the constraint inequality. Alternate Scheduling Method #3 calls for examinations to be scheduled from 1300 to 1500 on 15 days in each four-week period, which provides 27.5 additional hours of available examination time according to the following calculation:

$$(2 \text{ hours/day})(15) - (2)(15)(.082) = 27.5 \text{ hours per 4-week period}$$

The third constraint is expressed as ten separate constraint inequalities that will prevent the model from generating a solution that calls for more of a particular examination to be scheduled than is expected to be demanded. The expected demand for each type of examination is shown in Appendix E, but these figures include both scheduled and unscheduled examinations. The numbers of unscheduled examinations observed in the study period were subtracted from the quantities shown in Appendix E, so that the constants in the following constraint inequalities represent the expected demand for scheduled examinations during a four-week period.

$0.75X1 \leq 28$ $0.75X5 \leq 2$ $0.75X8 \leq 15$

$0.75X2 \leq 15$ $0.75X6 \leq 2$ $0.75X9 \leq 1$

$0.75X3 \leq 4$ $0.75X7 \leq 2$ $0.75X10 \leq 60$

$0.75X4 \leq 5$

The coefficient for each of the variables is 0.75 because the number of examinations actually performed during the study period was 25 percent less than the number of examinations that supposedly could have been scheduled. Patient cancellations and the unavailability of the radiologist because of leave, temporary duty, illness, etc., resulted in 35 scheduled examinations being performed when 47 appointments were supposedly available.

The model was run on a linear programming computer program. The printout of the optimal solution generated by the computer appears in Appendix G. The solution is also displayed in a more comprehendible format in Table 16.

TABLE 16

OPTIMAL MIX OF SCHEDULED EXAMINATIONS
ALTERNATE SCHEDULING METHOD #3

Examinations	Variable	Number of Exams to be Scheduled	Number of Exams Expected to be Performed	Expected Demand
Upper Gastrointestinal	X1	33.3	25	28
Barium Enema	X2	20	15	15
Barium Swallow	X3	0	0	4
Gall Bladder	X4	6.7	5	5
Small Bowel Follow-Through	X5	0	0	2
Arthrogram	X6	2.7	2	2
Venogram	X7	2.7	2	2
Intravenous Pyelogram	X8	20	15	15
Other Fluoroscopic and Special	X9	1.3	1	1
Mammogram	X10	80	60	60

The values of the primal variables in the computer printout correspond to the numbers of examinations to be scheduled. The numbers of examinations expected to be performed are 75 percent of the numbers of examinations to be scheduled. Alternate Scheduling Method #3 is expected to accomodate all of the demand for examinations except for three upper gastrointestinal, four barium swallow and two small bowel follow-through examinations. MACH would have to pay $297 to have these examinations performed at another hospital.

The linear programming model to determine the optimal mix of examinations to be scheduled for the Picker room under Alternate Scheduling Method #4 for the second three-month period of the EMU project is almost identical to the above model. The constants for the first two constraint inequalities are the only numbers that change. Alternate Scheduling Method #3 provides three hours each morning for scheduled examinations, so the time available during the morning in a four-week period drops from 4140 to 3300 minutes. The total time available drops from 5790 to 4950 minutes. The computer printout of the optimal solution for this model is shown in Appendix H. The comparison of the numbers of examinations expected to be scheduled, performed and demanded is presented in Table 17.

TABLE 17

OPTIMAL MIX OF SCHEDULED EXAMINATIONS
ALTERNATE SCHEDULING METHOD #4

Examinations	Variable	Number of Exams to be Scheduled	Number of Exams Expected to be Performed	Expected Demand
Upper Gastrointestinal	X1	7	5	28
Barium Enema	X2	20	15	15
Barium Swallow	X3	0	0	4
Gall Bladder	X4	6.7	5	5
Small Bowel Follow-Through	X5	0	0	2
Arthrogram	X6	2.7	2	2
Venogram	X7	2.7	2	2
Intravenous Pyelogram	X8	20	15	15
Other Fluoroscopic and Special	X9	1.3	1	1
Mammogram	X10	80	60	60

Twenty-three upper gastrointestinal, four barium swallow and two small bowel follow-through examinations would be sent to other hospitals under Alternate Scheduling Method #4. These procedures would cost MACH #1077 per four-week period.

The models for Alternate Scheduling Methods #3 and #4 were each run a second time to see what the optimal mix of scheduled examinations would be if the projected demand for each type of examination increased by 25 percent. The computer printouts of the results are at Appendixes I and J. The comparison of the numbers of examinations to be scheduled, performed and demanded are displayed in Tables 18 and 19.

TABLE 18

OPTIMAL MIX OF SCHEDULED EXAMINATIONS
ALTERNATE SCHEDULING METHOD #3
(25% Workload Increase)

Examinations	Variable	Number of Exams to be Scheduled	Number of Exams Expected to be Performed	Expected Demand
Upper Gastrointestinal	X1	0	0	35
Barium Enema	X2	24.7	19	19
Barium Swallow	X3	0	0	5
Gall Bladder	X4	0	0	6
Small Bowel Follow-Through	X5	0	0	3
Arthrogram	X6	4	3	3
Venogram	X7	4	3	3
Intravenous Pyelogram	X8	25.3	19	19
Other Fluoroscopic and Special	X9	1.3	1	1
Mammogram	X10	100	75	75

The optimal mix of scheduled examinations under Alternate Scheduling Method #3 with a 25 percent increase in expected demand would send 35 upper gastrointestinal, five barium swallow, six gall bladder and three small bowel follow-through examinations to other hospitals at a cost of $1785. In addition to the above examinations, 14 barium enemas would be sent out under Alternate Scheduling Method #4 for a total cost of $2905.

TABLE 19

OPTIMAL MIX OF EXAMINATIONS
ALTERNATE SCHEDULING METHOD #4
(25% Workload Increase)

Examinations	Variable	Number of Exams to be Scheduled	Number of Exams Expected to be Performed	Expected Demand
Upper Gastrointestinal	X1	0	0	35
Barium Enema	X2	6.8	5	19
Barium Swallow	X3	0	0	5
Gall Bladder	X4	0	0	6
Small Bowel Follow-Through	X5	0	0	3
Arthrogram	X6	4	3	3
Venogram	X7	4	3	3
Intravenous Pyelogram	X8	25.3	19	19
Other Fluoroscopic and Special	X9	1.3	1	1
Mammogram	X10	100	75	75

FOOTNOTES

[1]Howard M. Blanken, Geoffrey T. Fromme, and Robert B. Toffler, "Patient Scheduling System Improves Productivity," Hospitals 55 (16 April 1981):71.

[2]Richard I. Levin, Charles A. Kirkpatrick, and David S. Runib. Quantitative Approaches to Management (New York: McGraw-Hill Book Company, 1982), p. 335.

III. CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

This study was to determine the optimal method of scheduling radiological examinations during the electrical-mechanical upgrade project at Munson Army Community Hospital. Since the hospital will have only one examination room during the first three months and two examination rooms during the final six months of the project, two alternate scheduling methods were formulated and evaluated for each of the periods.

Alternate Scheduling Method #1 would eliminate the 0945 appointment slot from the current method of scheduling fluoroscopic and special examinations at 0900, 0945 and 1300. The analysis revealed that the average waiting times for patients arriving during the 0900 and 1000 arrival hours would be 85 and 72 minutes respectively, which exceed the 60-minute maximum average waiting time criterion.

Alternate Scheduling Method #2 would eliminate both the 0900 and 0945 appointment slots. The longest expected average patient waiting time under this scheduling method is 51 minutes for the 0900 arrival hour, which meets the waiting time criterion. Alternate Scheduling Method #2 is consequently selected as the optimal scheduling method for the first three months of the EMU project. Since the number of appointments

that will be available for the remaining 1300 appointment slot exceeds the expected demand for examinations at that hour, it was not necessary to use linear programming to determine the optimal mix of examinations to be scheduled.

Alternate Scheduling Method #3 devotes the Picker or General Electric examination rooms to scheduled examinations from 0730-1115 and 1300-1500 daily during the last six months of the EMU project. The analysis revealed that the service capacity of this room would exceed the average time that would be required to complete the examinations for each arrival hour of the day, so patient waiting time is expected to average less than 30 minutes.

The Phillips room is left to perform all the the general x-ray examinations. Although the average time required to complete the examinations would exceed the service capacity of the Phillips room during the 0800 arrival hour, the expected average patient waiting times are only 23 and 26 minutes for the 0800 and 0900 arrival hours, so the 30-minute patient waiting time criterion is met by both examination rooms under Alternate Scheduling Method #3.

Alternate Scheduling Method #4 devotes both available examination rooms to general x-ray examinations from 0730-0830 daily. This results in a 45-minute reduction in the time available for scheduled examinations in the Picker and General Electric examination rooms. Since Alternate Scheduling Method #4 would schedule fewer examinations than Alternate Scheduling

Method #3, Alternate Scheduling Method #4 will also meet the 30-minute patient waiting time criterion.

The optimal mix of examinations to be scheduled was determined through linear programming techniques for both scheduling method alternatives. Alternate Scheduling Method #3 nearly meets the expected demand for examinations. It is projected that only nine patients would be sent to other hospitals for examinations costing a total of $297 in a four-week period.

The optimal mix of examinations to be scheduled under Alternate Scheduling Method #4 would fall short of the expected demand by 29 patients. The examinations performed by other hospitals for these patients would cost the hospital $1077 per four-week period.

Both alternate scheduling methods meet the waiting time criterion. Alternate Scheduling Method #3 is selected as the optimal scheduling method for the final six months of the EMU project because it would send 20 fewer patients to other hospitals for examinations each four-week period at a savings of $780.

RECOMMENDATIONS

Conversion from the current method of scheduling examinations to Alternate Scheduling Method #2 would force MACH to pay for about 30 additional fluoroscopic and special

examinations with Supplemental Care funds every four weeks. Assuming the distribution of the examinations sent out is the same as the distribution of examinations that are expected to be demanded (Appendix E), the 30 examinations would cost MACH approximately $2250.

The Patient Administration Division would be affected by a change to Alternate Scheduling Method #2. The two Health Benefits Advisors are responsible for scheduling patients for examinations and for all the other administrative matters associated with the referral of examinations. They would have to shoulder the administrative burden of 30 additional referrals every four weeks.

This study identified the optimal scheduling method for a given set of constraints and criteria. The 60-minute maximum acceptable average waiting time criterion was established before the costs of meeting it were known. The additional costs identified above--monetary and administrative--should be compared to the benefits of reducing the longest hourly average patient waiting time from 94 to 51 minutes before Alternate Scheduling Method #2 is adopted.

Alternate Scheduling Method #3 calls for 30 mammograms to be scheduled during each four-week period. The Radiology Department should schedule one mammogram each morning in addition to the four that would be scheduled each afternoon in order to meet the projected demand.

The maximum acceptable waiting time for an appointment that

is noted on the examination request should no longer be the only factor used to decide whether a given fluoroscopic or special procedure is done at MACH or at some other facility. By comparing the examinations to be scheduled in Tables 16 and 18, it can be seen that the upper gastrointestinal examinations should be given priority for referral under Supplemental Care if the demand for examinations that is actually experienced during the last six months of the EMU project exceeds the projections in Appendix E.

RADIOLOGY DAILY REGISTER | MACH, FT. LEAVENWORTH, KS | RADIOLOGY DEPARTMENT | DATE: | PAGE:

UCA CODE	PATIENT IDENTIFICATION LAST NAME, FIRST NAME, MI	FMP	SSAN	CHEST RIBS		EXTREM-ITIES		HEAD SINUS		SPINE		UGI		BE		B/S		OCG		SBFT		IVP		KUB		ABD SERIES		OTHER SPECIAL		OTHER FLURO		PORT-ABLES		ULTRA-SOUND					
				I/P	O/P	I/P	O/P	I/P	O/P	I/P	O/P	I/P	O/P	I/P	O/P	I/P	O/P	I/P	O/P	I/P	O/P	I/P	O/P	I/P	O/P	I/P	O/P	I/P	O/P	I/P	O/P	I/P	O/P	I/P	O/P	I/P	O/P	I/P	O/P
5																																							
10																																							
15																																							
20																																							
25																																							
30																																							
35																																							
	TOTAL PATIENTS	I/P	O/P	TOTAL I/P PROCEDURES																																				
				TOTAL O/P PROCEDURES																																				

MACH FORM 252
1 Mar 83

84-MEDDAC-0043—1000—3 Nov 83

APPENDIX A

APPENDIX B

RADIOLOGY DAILY PROCEDURE SCHEDULE

DATE _____

EXAMINATION	PATIENT INFORMATION	DOCTOR	INITIAL	RESULTS
0730 Hours	NAME			
	SSN			
	PHONE #			
0815 Hours	NAME			
	SSN			
	PHONE #			
0900 Hours	NAME			
	SSN			
	PHONE #			
0945 Hours	NAME			
	SSN			
	PHONE #			
1030 Hours	NAME			
	SSN			
	PHONE #			
1300 Hours	NAME			
	SSN			
	PHONE			
1345 Hours	NAME			
	SSN			
	PHONE #			
1430 Hours	NAME			
	SSN			
	PHONE #			
1515 Hours	NAME			
	SSN			
	PHONE #			
On-call	NAME			
	SSN			
	PHONE #			
On-call	NAME			
	SSN			
	PHONE #			

APPENDIX C

MACH, Ft Leavenworth, KS 66027

NAME _____

SSN _____

DOB _____

MACH Form 51
15 May 85 (Rev)
8o 1839—1000—Feb 8b

MACH, Ft Leavenworth, KS 66027

NAME _____

SSN _____

DOB _____

APPENDIX D

STUDY PERIOD DATA BASE

Explanation of Data Elements

Column #1: Record number

The computer program consecutively numbers each record as the data elements are entered into the data base.

Column #2: Day that the examination was performed

FRI1 stands for Friday of the first week, MON3 stands for Monday of the third week, etc.

Column #3: Service that requested the examination

The abbreviations stand for the following services:

ALGY	Allergy Clinic	OBGY	Obstetrics/Gynecology
COMH	Community Health Service	ORTH	Orthopedics
DENT	Dental Clinic	PEDS	Pediatrics
EENT	Eyes, Ears, Nose and Throat Clinic	PT	Physical Therapy
		SURG	General Surgery
EMER	Emergency Room	WD2B	Ward 2B
FAMP	Family Practice Clinic	WD2C	Ward 2C
GOPC	General Outpatient Clinic	WD3B	Ward 3B
INTM	Internal Medicine	USDB	U.S. Disciplinary Barracks Ward
MEDX	Medical Exam Clinic		
MENT	Mental Health Clinic	USDB	U.S. Disciplinary Barracks Clinic

Column #4: Type of examination performed

The abbreviations stand for the following types of examinations:

ABD	Abdominal Series	KUB	Kidneys/Ureters/Bladder
ARTH	Arthrogram	MULT	Multiple Examinations
BE	Barium Enema	SPEC	Other Special Examinations
CHST	Chest/Ribs	SPIN	Spine
EXTR	Extremeties	TOMO	Tomogram
FLUR	Other Fluoroscopic	UGI	Upper Gastrointestinal
HEAD	Head/Sinus	XERO	Xerogram
IVP	Intravenous Pyelogram		

Column #5: Arrival hour

Hour of the day that the patient arrived in the radiology department is noted as follows:

0800:	0730-0829	1300:	1230-1329
0900:	0830-0929	1400:	1330-1429
1000:	0930-1029	1500:	1530-1529
1100:	1030-1129	1600:	1530-1600
1200:	1130-1229		

Column #6: Waiting time

The waiting time is the number of minutes from the time the patient arrived at the Radiology Department until the patient entered the examination room.

Column #7: Service time

The service time is the number of minutes that the patient actually occupied the examination room.

Column #8: Transition tire

The transition time is the number of minutes elapsed from the time a patient departs the examination room until the next patient, who has been waiting, enters the examination room.

```
  LIST FOR DAY='FRI1'
00001   FRI1 ORTH EXTR 0800    10     5    15
00002   FRI1 MEDX MULT 0800    36     5     0
00003   FRI1 USDB SPIN 0800    28    15     0
00004   FRI1 USDB EXTR 0800    36     4     3
00005   FRI1 SURG CHST 0800    47     4     1
00006   FRI1 ORTH EXTR 0800    52     2     3
00007   FRI1 USDB EXTR 0800    49     6     9
00008   FRI1 USDB SPIN 0800    68     5     5
00009   FRI1 GOPC SPIN 0800    68     7     7
00010   FRI1 MEDX CHST 0800   168     5     1
00011   FRI1 GOPC EXTR 0800   116     5    21
00012   FRI1 WD3B CHST 0800   104     5     2
00013   FRI1 GOPC HEAD 0800   167     4    10
00014   FRI1 FAMP BE   0800    45    45    12
00015   FRI1 INTM BE   1000   166    45     7
00016   FRI1 GOPC EXTR 0900   283     3     0
00017   FRI1 EMER EXTR 1100     5     5    20
00018   FRI1 GOPC EXTR 0900   286     5     0
00019   FRI1 GOPC EXTR 0900   295     4     1
00020   FRI1 FAMP SPIN 0900   274    11    10
00021   FRI1 GOPC CHST 0900   285     4     0
00022   FRI1 FAMP EXTR 1000   271    18     2
00023   FRI1 FAMP SPIN 1000   273     2     4
00024   FRI1 GOPC EXTR 1000   322     5     0
00025   FRI1 FAMP EXTR 1100   283     5     2
00026   FRI1 EMER MULT 1100     5    80     0
00027   FRI1 USDB EXTR 1300   192     5     0
00028   FRI1 GOPC EXTR 1300   177     4     0
00029   FRI1 GOPC CHST 1300   178     3     5
00030   FRI1 GOPC SPIN 1300   160     6     0
00031   FRI1 GOPC CHST 1300   173     3    14
00032   FRI1 SURG EXTR 1500   100     3     1
00033   FRI1 PEDS EXTR 1500    98     4     4
00034   FRI1 GOPC CHST 1500    97     3     0
00035   FRI1 PEDS EXTR 1500    90     3     8
00036   FRI1 WD3B CHST 1600     0     5     0
00037   FRI1 WD3B CHST 1600    19     2     0
00038   FRI1 EMER MULT 1500     5    65     0
000. 9  FRI1 EMER EXTR 1600    55     3     0
00040   FRI1 INTM SPIN 1600    52     4     0
```

```
  LIST FOR DAY='MON1'
00041   MON1 ORTH SPIN 0800    24     2     8
00042   MON1 GOPC EXTR 0800    35     4     0
00043   MON1 EMER EXTR 0800    37     4     2
00044   MON1 INTM CHST 0800    42     3     4
00045   MON1 PEDS SPIN 0800    51     3     9
00046   MON1 GOPC EXTR 0800    57     2    11
00047   MON1 WD3E CHST 0900     1     4     6
00048   MON1 USDB EXTR 0800    78     5     0
00049   MON1 GOPC CHST 0800    89     2     5
00050   MON1 MEDX CHST 0800    83     2     1
00051   MON1 GOPC CHST 0800    78     4     9
00052   MON1 ORTH EXTR 0800    92     1     1
00053   MON1 EMER EXTR 0800    64     2    17
00054   MON1 GOPC EXTR 0800    82     5     9
00055   MON1 GOPC EXTR 0800    92     7     5
00056   MON1 GOPC EXTR 0900    83     9     5
00057   MON1 EMER EXTR 0900   101     3     0
00058   MON1 GOPC EXTR 0900   107     2     2
00059   MON1 PEDS EXTR 0900    80     3    11
00060   MON1 GOPC SPIN 0900    93    14     4
00061   MON1 GOPC EXTR 1000    81     3     0
00062   MON1 GOPC EXTR 1000    75    16     0
00063   MON1 PEDS EXTR 1000    80    17     0
00064   MON1 WD3B CHST 1100    70     4     6
00065   MON1 WD3B IVP  1200    20    55     0
00066   MON1 INTM CHST 1100   119     5     5
00067   MON1 GOPC EXTR 1200    77     5     1
00068   MON1 ORTH EXTR 1200    86     4    20
00069   MON1 ORTH EXTR 1200   110     4     1
00070   MON1 EMER CHST 1200    81     2     1
00071   MON1 FAMP EXTR 1200    82     1     6
00072   MON1 EMER EXTR 1200    68     5     0
00073   MON1 WD3B EXTR 1300    13     6    11
00074   MON1 GOPC EXTR 1300    31     3     0
00075   MON1 INTM CHST 1400    19     5     6
00076   MON1 PEDS EXTR 1400    25     3     0
00077   MON1 FAMP EXTR 1400    18     3     3
00078   MON1 PEDS EXTR 1400     8     4    35
00079   MON1 ORTH EXTR 1500    35     8     2
00080   MON1 GOPC HEAD 1500    42    10     1
00081   MON1 GOPC EXTR 1500    47    10     9
00082   MON1 INTM CHST 1500    64     3     0
00083   MON1 ORTH EXTR 1500    57     2     0
00084   MON1 ORTH EXTR 1500    49     3     4
00085   MON1 GOPC EXTR 1600    43     3     8
00086   MON1 WD3B MULT 1600    35     8     1
00087   MON1 EMER EXTR 1600    37     4     0
```

LIST FOR DAY='TUE1'

00088	TUE1	ORTH	CHST	0800	15	2	5
00089	TUE1	ORTH	EXTR	0800	15	4	4
00090	TUE1	ORTH	EXTR	0800	28	4	1
00091	TUE1	FAMP	EXTR	0800	33	10	4
00092	TUE1	INTM	KUB	0800	29	5	5
00093	TUE1	GOPC	EXTR	0800	26	3	2
00094	TUE1	ORTH	EXTR	0800	19	6	8
00095	TUE1	MEDX	CHST	0800	25	2	3
00096	TUE1	PT	EXTR	0800	31	4	1
00097	TUE1	MEDX	CHST	0800	29	2	15
00098	TUE1	FAMP	EXTR	0900	45	2	3
00099	TUE1	GOPC	SPIN	0900	39	10	15
00100	TUE1	GOPC	UGI	0900	45	20	10
00101	TUE1	GOPC	SPIN	0900	84	25	15
00102	TUE1	GOPC	UGI	1000	75	25	2
00103	TUE1	MEDX	CHST	0900	154	1	13
00104	TUE1	MEDX	CHST	0900	131	2	2
00105	TUE1	GOPC	CHST	0900	154	1	0
00106	TUE1	GOPC	SPIN	0900	157	3	2
00107	TUE1	FAMP	CHST	0900	165	3	9
00108	TUE1	MEDX	MULT	1000	131	12	7
00109	TUE1	ORTH	EXTR	1000	122	4	2
00110	TUE1	PEDS	ABD	1000	125	2	20
00111	TUE1	EMER	HEAD	1000	145	15	2
00112	TUE1	GOPC	SPIN	1100	108	6	3
00113	TUE1	INTM	CHST	1100	139	3	3
00114	TUE1	ORTH	SPIN	1300	25	3	0
00115	TUE1	ORTH	SPIN	1300	10	15	7
00116	TUE1	GOPC	EXTR	0900	160	6	12
00117	TUE1	FAMP	EXTR	1000	120	15	5
00118	TUE1	GOPC	EXTR	1300	80	5	23
00119	TUE1	GOPC	CHST	1400	69	3	4
00120	TUE1	GOPC	EXTR	1400	71	2	1
00121	TUE1	GOPC	EXTR	1500	8	3	2
00122	TUE1	INTM	CHST	1000	120	3	8
00123	TUE1	MENT	CHST	1400	89	3	1
00124	TUE1	EMER	CHST	1500	42	2	6
00125	TUE1	ORTH	EXTR	1500	36	6	13
00126	TUE1	GOPC	HEAD	1000	158	5	2
00127	TUE1	FAMP	EXTR	1600	29	3	0

```
  LIST FOR DAY='WED1'
00128   WED1 PEDS SPIN 0800     2     6     7
00129   WED1 MEDX CHST 0800    14     2     3
00130   WED1 PEDS EXTR 0800    15     8     4
00131   WED1 MEDX CHST 0800    28     2    13
00132   WED1 MEDX CHST 0800    20     2     2
00133   WED1 FAMP EXTR 0800    23     4    10
00134   WED1 WD2B UGI  0800    40    33     1
00135   WED1 MEDX CHST 0800    85     4     1
00136   WED1 GOPC EXTR 0800    73     3     3
00137   WED1 MEDX CHST 0800    77     4     6
00138   WED1 INTM BE   0900    29    55     0
00139   WED1 FAMP EXTR 0800   157     6     1
00140   WED1 MEDX CHST 0800   126     4     2
00141   WED1 INTM CHST 0800   137     3     2
00142   WED1 GOPC EXTR 0900   132     4     3
00143   WED1 OBGY IVP  1000    65    35    14
00144   WED1 MEDX SP N 0900   158     3    11
00145   WED1 GOPC CHST 0900   139     2     2
00146   WED1 PEDS CHST 1000   101     6     4
00147   WED1 GOPC SPIN 1000   107    15     3
00148   WED1 ORTH EXTR 1000   105     3     8
00149   WED1 FAMP EXTR 1100   114     2     0
00150   WED1 FAMP SPIN 1100    86    20     5
00151   WED1 ORTH EXTR 1100    94     2     1
00152   WED1 GOPC CHST 1100   100     4     8
00153   WED1 EMER EXTR 1200    94     4     0
00154   WED1 FAMP EXTR 1200    93     5    23
00155   WED1 EMER HEAD 1300    15    27     4
00156   WED1 FAMP CHST 1200   143     4     2
00157   WED1 GOPC CHST 1300   105     2     2
00158   WED1 FAMP KUB  1300    69     2     7
00159   WED1 GOPC EXTR 1300    71     6     ?
00160   WED1 FAMP CHST 1300    68     2    11
00161   WED1 GOPC SPIN 1400    41     4     1
00162   WED1 INTM CHST 1400    34     2    10
00163   WED1 FAMP CHST 1500    28     3     1
00164   WED1 GOPC CHST 1500    28     2    11
00165   WED1 WD2C CHST 1500    18     3    11
00166   WED1 EMER EXTR 1500    30    28     4
00167   WED1 FAMP EXTR 1500    60     4     2
00168   WED1 FAMP SPIN 1500    59     8     2
00169   WED1 GOPC MULT 1500    66     9     1
00170   WED1 EMER SPIN 1500    73     8     0
```

LIST FOR DAY='THU1'

00171	THU1	INTM	SPIN	0800	18	26	4
00172	THU1	ORTH	EXTR	0800	48	2	1
00173	THU1	ORTH	EXTR	0800	51	3	6
00174	THU1	GOPC	EXTR	0800	41	2	22
00175	THU1	GOPC	SPIN	0800	65	9	2
00176	THU1	INTM	UGI	0800	73	40	5
00177	THU1	MEDX	CHST	0800	117	1	1
00178	THU1	MEDX	CHST	0800	114	2	1
00179	THU1	MEDX	SPIN	0900	85	3	4
00180	THU1	WD3B	IVP	1000	15	52	5
00181	THU1	INTM	CHST	0900	98	2	1
00182	THU1	GOPC	SPIN	0900	148	21	2
00183	THU1	ORTH	EXTR	0900	108	1	0
00184	THU1	FAMP	CHST	0900	152	2	6
00185	THU1	ORTH	EXTR	1100	85	14	0
00186	THU1	FAMP	EXTR	0900	155	3	4
00187	THU1	EMER	EXTR	1200	19	15	2
00188	THU1	GOPC	EXTR	1000	167	4	8
00189	THU1	FAMP	EXTR	0900	170	4	3
00190	THU1	MEDX	EXTR	1000	164	2	2
00191	THU1	ORTH	EXTR	1000	161	5	3
00192	THU1	ORTH	EXTR	1000	163	3	2
00193	THU1	ORTH	EXTR	1000	164	4	10
00194	THU1	GOPC	CHST	1000	169	7	1
00195	THU1	GOPC	EXTR	1000	169	7	3
00196	THU1	ORTH	EXTR	0900	150	6	0
00197	THU1	ORTH	EXTR	1100	144	4	6
00198	THU1	EMER	SPIN	1100	145	5	0
00199	THU1	GOPC	SPIN	1100	139	8	4
00200	THU1	ORTH	EXTR	1100	168	5	5
00201	THU1	ORTH	EXTR	1200	115	6	13
00202	THU1	ORTH	EXTR	1100	177	2	1
00203	THU1	FAMP	CHST	1400	20	4	0
00204	THU1	ORTH	EXTR	1300	60	11	13
00205	THU1	FAMP	CHST	1400	68	5	1
00206	THU1	EMER	EXTR	1400	30	6	5
00207	THU1	FAMP	EXTR	1000	155	4	1
00208	THU1	EMER	EXTR	1200	150	3	6
00209	THU1	FAMP	CHST	1500	6	11	7
00210	THU1	ORTH	EXTR	1600	10	4	1
00211	THU1	GOPC	CHST	1700	15	2	5
00212	THU1	GOPC	EXTR	1600	13	2	1
00213	THU1	GOPC	EXTR	1600	5	4	0

LIST FOR DAY='FRI2'

00214	FRI2	GOPC	IVP	0800	9	35	5
00215	FRI2	PEDS	IVP	0800	21	45	8
00216	FRI2	FAMP	CHST	0800	108	5	1
00217	FRI2	PEDS	SPIN	0800	115	2	0
00218	FRI2	FAMP	SPIN	0800	116	4	10
00219	FRI2	FAMP	CHST	0800	129	4	0
00220	FRI2	ORTH	EXTR	0800	131	3	1
00221	FRI2	EMER	EXTR	0800	137	4	4
00222	FRI2	FAMP	EXTR	0800	143	1	2
00223	FRI2	ORTH	EXTR	0900	88	1	1
00224	FRI2	GOPC	CHST	0900	81	2	1
00225	FRI2	PEDS	EXTR	0900	81	5	1
00226	FRI2	GOPC	MULT	0900	84	6	7
00227	FRI2	PEDS	EXTR	1000	42	2	2
00228	FRI2	EMER	EXTR	1000	45	2	7
00229	FRI2	PEDS	CHST	0900	94	4	6
00230	FRI2	USDB	EXTR	1000	25	2	1
00231	FRI2	USDB	CHST	1000	28	1	1
00232	FRI2	USDB	HEAD	1000	31	9	7
00233	FRI2	GOPC	EXTR	1000	75	3	1
00234	FRI2	FAMP	CHST	1000	78	5	5
00235	FRI2	PEDS	EXTR	1000	60	2	2
00236	FRI2	INTM	EXTR	1000	56	3	3
00237	FRI2	PT	EXTR	1100	43	4	2
00238	FRI2	SURG	CHST	1100	57	3	7
00239	FRI2	FAMP	EXTR	1100	45	2	1
00240	FRI2	FAMP	CHST	1100	47	7	1
00241	FRI2	FAMP	CHST	1100	36	1	7
00242	FRI2	ORTH	EXTR	1200	21	3	9
00243	FRI2	WDDB	EXTR	1200	8	2	5
00244	FRI2	EMER	EXTR	1200	5	3	9
00245	FRI2	ALGY	MULT	0800	88	17	7
00246	FRI2	INTM	CHST	1400	7	16	3
00247	FRI2	GOPC	SPIN	1400	45	14	6
00248	FRI2	EMER	SPIN	1400	39	28	0
00249	FRI2	EMER	SPIN	1400	73	3	6
00250	FRI2	GOPC	EXTR	1500	31	2	1
00251	FRI2	FAMP	SPIN	1500	22	10	8
00252	FRI2	EMER	EXTR	1500	38	4	0
00253	FRI2	GOPC	EXTR	1600	23	4	0

LIST FOR DAY='MON2'

00254	MON2	FAMP	SPIN	0800	11	19	1
00255	MON2	MEDX	CHST	0800	30	3	1
00256	MON2	MEDX	CHST	0800	35	1	10
00257	MON2	GOPC	HEAD	0800	36	4	2
00258	MON2	ORTH	EXTR	0800	25	17	6
00259	MON2	MEDX	CHST	0800	37	2	5
00260	MON2	ORTH	EXTR	0800	36	5	3
00261	MON2	MEDX	CHST	0800	44	2	1
00262	MON2	INTM	IVP	0900	32	77	1
00263	MON2	ORTH	EXTR	1000	31	1	10
00264	MON2	WD3B	CHST	1000	12	2	1
00265	MON2	OBGY	IVP	1000	58	25	9
00266	MON2	INTM	HEAD	1000	49	5	1
00267	MON2	ORTH	EXTR	1100	35	3	37
00268	MON2	WD3B	BE	1200	5	25	3
00269	MON2	EMER	SPIN	1100	88	7	1
00270	MON2	EMER	CHST	1300	1	3	4
00271	MON2	INTM	MULT	1100	105	4	0
00272	MON2	ORTH	EXTR	1100	83	3	3
00273	MON2	GOPC	HEAD	1200	66	10	4
00274	MON2	ORTH	EXTR	1200	74	10	2
00275	MON2	EMER	HEAD	1300	12	7	0
00276	MON2	FAMP	CHST	1300	10	3	1
00277	MON2	FAMP	MULT	1300	8	16	0
00278	MON2	MEDX	EXTR	1400	9	8	13
00279	MON2	WD3B	BE	1400	0	58	0
00280	MON2	GOPC	CHST	1400	41	10	17
00281	MON2	ORTH	EXTR	1400	65	2	1
00282	MON2	WD3B	CHST	1500	60	2	0
00283	MON2	MEDX	EXTR	1600	0	6	0

LIST FOR DAY='TUE2'

00284	TUE2	INTM	EXTR	0800	7	1	0
00285	TUE2	MEDX	CHST	0800	6	3	4
00286	TUE2	ORTH	EXTR	0800	3	4	1
00287	TUE2	MEDX	CHST	0800	5	1	6
00288	TUE2	WD2B	CHST	0800	30	4	5
00289	TUE2	PT	EXTR	0800	2	5	8
00290	TUE2	FAMP	EXTR	0800	13	6	3
00291	TUE2	MEDX	CHST	0800	29	2	6
00292	TUE2	EMER	CHST	0900	6	4	3
00293	TUE2	GOPC	EXTR	0900	13	7	7
00294	TUE2	INTM	BE	0900	16	51	2
00295	TUE2	ORTH	EXTR	0900	62	4	0
00296	TUE2	GOPC	UGI	0900	62	30	2
00297	TUE2	MEDX	CHST	0900	107	4	1
00298	TUE2	ORTH	EXTR	0900	96	3	4
00299	TUE2	INTM	EXTR	0900	98	7	2
00300	TUE2	INTM	EXTR	0900	100	23	0
00301	TUE2	ORTH	EXTR	1100	46	10	2
00302	TUE2	MEDX	CHST	1000	112	3	1
00303	TUE2	ORTH	SPIN	1000	95	13	1
00304	TUE2	ORTH	EXTR	1000	97	5	2
00305	TUE2	MEDX	CHST	1000	124	2	0
00306	TUE2	ORTH	EXTR	1000	103	4	13
00307	TUE2	ORTH	SPIN	1000	104	14	1
00308	TUE2	GOPC	CHST	1100	103	9	13
00309	TUE2	PEDS	SPIN	1100	123	3	3
00310	TUE2	GOPC	SPIN	1100	122	4	1
00311	TUE2	ORTH	EXTR	1200	84	1	8
00312	TUE2	GOPC	CHST	1200	83	4	1
00313	TUE2	FAMP	EXTR	1200	89	3	2
00314	TUE2	INTM	CHST	1200	77	3	2
00315	TUE2	ORTH	EXTR	1200	103	2	5
00316	TUE2	GOPC	CHST	1300	31	5	1
00317	TUE2	EMER	EXTR	1200	74	4	0
00318	TUE2	ORTH	EXTR	1300	25	1	1
00319	TUE2	FAMP	SPIN	1300	30	3	1
00320	TUE2	GOPC	CHST	1300	17	3	1
00321	TUE2	ORTH	EXTR	1400	14	3	8
00322	TUE2	EMER	EXTR	1400	27	9	1
00323	TUE2	INTM	SPIN	1400	25	15	1
00324	TUE2	MEDX	CHST	1400	28	1	6
00325	TUE2	ORTH	EXTR	1400	29	3	4
00326	TUE2	ORTH	HEAD	1500	16	15	7
00327	TUE2	GOPC	EXTR	1500	38	5	7
00328	TUE2	GOPC	CHST	1500	58	4	9
00329	TUE2	GOPC	MULT	1500	63	8	1
00330	TUE2	GOPC	EXTR	1500	53	2	15
00331	TUE2	EMER	EXTR	1500	77	4	6
00332	TUE2	ORTH	EXTR	1500	68	3	1
00333	TUE2	GOPC	HEAD	1500	82	15	1
00334	TUE2	EMER	SPIN	1600	46	9	0

LIST FOR DAY='WED2'

00335	WED2	EMER	EXTR	0800	1	2	16
00336	WED2	ORTH	EXTR	0800	16	1	12
00337	WED2	ORTH	EXTR	0800	12	2	3
00338	WED2	MEDX	CHST	0900	9	1	2
00339	WED2	OBGY	IVP	0900	2	50	0
00340	WED2	FAMP	IVP	1000	0	40	0
00341	WED2	GOPC	SPIN	0900	47	10	0
00342	WED2	INTM	CHST	1000	28	10	18
00343	WED2	PEDS	EXTR	1100	18	3	1
00344	WED2	GOPC	CHST	1100	16	3	0
00345	WED2	GOPC	EXTR	0900	55	2	3
00346	WED2	GOPC	SPIN	1100	21	5	1
00347	WED2	GOPC	CHST	1200	1	3	8
00348	WED2	FAMP	EXTR	1200	9	3	10
00349	WED2	EMER	SPIN	1300	10	15	0
00350	WED2	INTM	CHST	1300	7	10	3
00351	WED2	GOPC	SPIN	1300	12	8	9
00352	WED2	GOPC	CHST	1300	8	3	0
00353	WED2	FAMP	CHST	1300	24	1	4
00354	WED2	WD2C	SPEC	1400	4	84	5
00355	WED2	MEDX	CHST	1400	61	2	1
00356	WED2	EMER	CHST	1400	51	2	1
00357	WED2	OBGY	CHST	1400	54	1	3
00358	WED2	ORTH	EXTR	1500	48	3	1
00359	WED2	FAMP	KUB	1500	52	7	3
00360	WED2	ORTH	EXTR	1600	13	4	10
00361	WED2	GOPC	EXTR	1600	10	5	0

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. LIST FOR DAY='THU2'
00362  THU2 GOPC EXTR 0800   15    3    9
00363  THU2 MEDX CHST 0800    9    2    8
00364  THU2 GOPC EXTR 0800    8   14    0
00365  THU2 MEDX CHST 0800   17    1    0
00366  THU2 GOPC CHST 0800   14   10    0
00367  THU2 ORTH EXTR 0800   23   10    1
00368  THU2 GOPC EXTR 0800   27    4    0
00369  THU2 GOPC CHST 0900   20    2    8
00370  THU2 WD2C SPEC 0900    2   69    0
00371  THU2 GOPC SPIN 0900   55   20    1
00372  THU2 ORTH EXTR 0900  103    6    0
00373  THU2 GOPC EXTR 0900  105    2    2
00374  THU2 MEDX CHST 0900   52    2    1
00375  THU2 FAMP EXTR 0900  114    2    3
00376  THU2 GOPC EXTR 0900  109    6   13
00377  THU2 INTM HEAD 0900  106    8   12
00378  THU2 GOPC SPIN 1000  115    2    1
00379  THU2 GOPC CHST 1000  107    3    3
00380  THU2 ORTH EXTR 1000   98    3    3
00381  THU2 ORTH HEAD 1000   91    4    1
00382  THU2 INTM CHST 1000   88    2    3
00383  THU2 ORTH EXTR 1100   85    3    3
00384  THU2 EMER EXTR 1100   68    3    4
00385  THU2 ORTH EXTR 1100   76    2    5
00386  THU2 ORTH EXTR 1100   57   10    6
00387  THU2 FAMP SPIN 1100   73   17    1
00388  THU2 ORTH EXTR 1200   82   10    1
00389  THU2 ORTH EXTR 1200   87    1    2
00390  THU2 GOPC EXTR 1100   88    3    2
00391  THU2 FAMP CHST 1200   72    6    1
00392  THU2 INTM SPIN 1300   49   11    1
00393  THU2 GOPC EXTR 1300   25    4   11
00394  THU2 ORTH EXTR 1400   11   10   10
00395  THU2 MEDX EXTR 1400   15    5    2
00396  THU2 ORTH EXTR 1400   20    1    7
00397  THU2 FAMP HEAD 1500    7    8    0
00398  THU2 GOPC EXTR 0900  100    4    0
00399  THU2 WD3B CHST 1500    1    2    5
00400  THU2 ORTH EXTR 1600    5   10    0
. LIST FOR DAY='FRI3'
00401  FRI3 ORTH SPIN 0800    5    9    5
00402  FRI3 INTM UGI  0800   17   20   10
00403  FRI3 EMER CHST 0900   36    3    2
00404  FRI3 GOPC CHST 0800   35    2    8
00405  FRI3 INTM IVP  0800   44   28    1
00406  FRI3 WD3B CHST 0900    2    3    0
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. LIST FOR DAY='MON3'
00407   MON3 MEDX EXTR 0800     4     3    14
00408   MON3 EMER EXTR 0800    12     4    17
00409   MON3 SURG CHST 0800    35     1     3
00410   MON3 GOPC EXTR 0800    36     3     6
00411   MON3 USDB EXTR 0800    40     2     1
00412   MON3 USDB SPIN 0800    43     2     4
00413   MON3 USDB HEAD 0800    49     5     9
00414   MON3 GOPC CHST 0800    63     2     3
00415   MON3 GOPC CHST 0800    66     2     5
00416   MON3 FAMP UGI  0800    70    30     8
00417   MON3 MEDX CHST 0800   101     2     1
00418   MON3 MEDX EXTR 0800    96     4     3
00419   MON3 ORTH EXTR 0800    98     2     4
00420   MON3 INTM CHST 0900    75     2     1
00421   MON3 GOPC SPIN 0800    97     3     1
00422   MON3 GOPC BE   1000    19    44    14
00423   MON3 ORTH EXTR 0900   118     4    10
00424   MON3 ORTH EXTR 0900   156     3    10
00425   MON3 MEDX CHST 0900   130     1     1
00426   MON3 MEDX CHST 0900   112     2     3
00427   MON3 MEDX EXTR 1000   115     2     5
00428   MON3 ORTH EXTR 1000   116     4     4
00429   MON3 GOPC CHST 1000   100     2     4
00430   MON3 MEDX CHST 1000   120     4    16
00431   MON3 MEDX CHST 1100    63     2     6
00432   MON3 ORTH EXTR 1100    96     4     6
00433   MON3 ORTH EXTR 1000   133    16     4
00434   MON3 ORTH EXTR 1200    76     1     1
00435   MON3 GOPC CHST 1200    80     3     4
00436   MON3 EMER EXTR 1200    66     6     0
00437   MON3 FAMP SPIN 1200    63     7    12
00438   MON3 GOPC EXTR 1300    54     3     7
00439   MON3 GOPC CHST 1300    54     3     0
00440   MON3 GOPC EXTR 1300    56    15     5
00441   MON3 OBGY FLUR 1300    68    45    15
00442   MON3 WD3B BE   1500    35    53     0
00443   MON3 GOPC SPIN 1400   103     6    10
00444   MON3 WD3B CHST 1500    59     4     3
00445   MON3 GOPC MULT 1200    65    10     0
00446   MON3 WD2C EXTR 1500    76     4     0
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LIST FOR DAY='TUE3'

00447	TUE3	GOPC	HEAD	0800	3	14	1
00448	TUE3	ORTH	EXTR	0800	13	5	1
00449	TUE3	ORTH	EXTR	0800	19	15	0
00450	TUE3	MEDX	CHST	0800	32	3	1
00451	TUE3	MEDX	CHST	0800	35	2	1
00452	TUE3	ORTH	EXTR	0800	30	5	1
00453	TUE3	GOPC	EXTR	0800	27	6	1
00454	TUE3	EMER	EXTR	0900	7	5	2
00455	TUE3	COMH	EXTR	0800	22	4	2
00456	TUE3	GOPC	EXTR	0800	31	4	4
00457	TUE3	GOPC	EXTR	0900	27	6	5
00458	TUE3	COMH	CHST	0900	34	3	6
00459	TUE3	ORTH	EXTR	0900	33	2	4
00460	TUE3	FAMP	EXTR	0900	17	3	2
00461	TUE3	MEDX	CHST	0900	19	1	11
00462	TUE3	GOPC	BE	1000	14	44	1
00463	TUE3	FAMP	HEAD	1000	57	8	2
00464	TUE3	EMER	EXTR	1100	2	15	3
00465	TUE3	ORTH	EXTR	1000	82	4	3
00466	TUE3	ORTH	SPIN	1000	84	12	5
00467	TUE3	EMER	EXTR	1000	99	2	1
00468	TUE3	GOPC	SPIN	1000	100	3	1
00469	TUE3	MEDX	CHST	1000	102	1	2
00470	TUE3	MEDX	CHST	1000	109	1	1
00471	TUE3	ORTH	EXTR	1000	109	8	5
00472	TUE3	ORTH	MULT	1000	117	31	0
00473	TUE3	ORTH	EXTR	1000	140	2	7
00474	TUE3	ORTH	EXTR	1000	146	2	2
00475	TUE3	ORTH	EXTR	1000	147	2	2
00476	TUE3	EMER	CHST	1100	108	3	1
00477	TUE3	GOPC	MULT	1100	112	13	0
00478	TUE3	FAMP	SPIN	1200	71	10	10
00479	TUE3	ORTH	XERO	1300	25	60	5
00480	TUE3	EMER	KUB	1200	144	10	1
00481	TUE3	COMH	CHST	1200	154	4	5
00482	TUE3	GOPC	CHST	1200	142	7	8
00483	TUE3	USDB	TOMO	1300	107	55	2
00484	TUE3	ORTH	EXTR	1400	111	4	0
00485	TUE3	ORTH	MULT	1400	132	10	3
00486	TUE3	INTM	CHST	1400	115	3	0
00487	TUE3	INTM	EXTR	1400	132	4	3
00488	TUE3	ORTH	EXTR	1400	153	11	0
00489	TUE3	INTM	SPEC	1400	126	35	0

LIST FOR DAY='WED3'

00490	WED3	MEDX	CHST	0800	10	3	0
00491	WED3	ORTH	SPIN	0800	13	4	5
00492	WED3	FAMP	CHST	0800	20	2	0
00493	WED3	EENT	HEAD	0800	12	6	4
00494	WED3	ORTH	EXTR	0800	14	3	7
00495	WED3	GOPC	EXTR	0800	19	1	1
00496	WED3	OBGY	CHST	0800	25	2	1
00497	WED3	GOPC	EXTR	0800	17	2	1
00498	WED3	GOPC	EXTR	0800	17	5	9
00499	WED3	EMER	EXTR	0900	9	2	0
00500	WED3	EMER	EXTR	0900	11	4	0
00501	WED3	GOPC	UGI	0900	10	30	22
00502	WED3	GOPC	EXTR	1000	3	6	29
00503	WED3	GOPC	UGI	0900	65	20	4
00504	WED3	FAMP	EXTR	1000	33	2	7
00505	WED3	FAMP	SPIN	1100	7	6	11
00506	WED3	PEDS	SPIN	1100	24	7	14
00507	WED3	GOPC	CHST	1200	22	2	1
00508	WED3	GOPC	CHST	1200	29	5	7
00509	WED3	GOPC	CHST	1200	33	2	2
00510	WED3	EMER	SPIN	1200	35	36	7
00511	WED3	INTM	CHST	1200	42	3	1
00512	WED3	COMH	CHST	1300	29	2	11
00513	WED3	MEDX	CHST	1300	26	11	0
00514	WED3	EMER	HEAD	1300	33	25	5
00515	WED3	OBGY	IVP	1400	13	30	12
00516	WED3	ORTH	EXTR	1300	82	6	5
00517	WED3	GOPC	EXTR	1300	92	3	1
00518	WED3	ORTH	EXTR	1400	69	3	2
00519	WED3	FAMP	CHST	1400	75	2	1
00520	WED3	ORTH	EXTR	1400	79	4	1
00521	WED3	ORTH	EXTR	1400	83	3	2
00522	WED3	ORTH	EXTR	1500	38	5	9
00523	WED3	GOPC	CHST	1500	30	1	0
00524	WED3	SURG	CHST	1500	26	1	3
00525	WED3	ORTH	EXTR	00	9	9	0
00526	WED3	PEDS	SPIN	00	6	15	0

LIST FOR DAY='THU3'

00527	THU3	FAMP	SPIN	0800	5	15	9
00528	THU3	INTM	CHST	0800	6	11	17
00529	THU3	FAMP	CHST	0800	12	4	6
00530	THU3	ORTH	SPIN	0900	5	16	0
00531	THU3	ORTH	EXTR	0900	22	4	1
00532	THU3	FAMP	EXTR	0900	20	2	5
00533	THU3	OBGY	IVP	0900	29	44	5
00534	THU3	EMER	CHST	0900	62	11	2
00535	THU3	GOPC	EXTR	0900	72	6	4
00536	THU3	ORTH	SPIN	0900	70	11	1
00537	THU3	ORTH	EXTR	0900	80	3	0
00538	THU3	GOPC	EXTR	1000	58	5	2
00539	THU3	ORTH	EXTR	1000	56	3	0
00540	THU3	FAMP	CHST	1000	58	3	1
00541	THU3	GOPC	EXTR	1000	36	2	3
00542	THU3	WD3B	SPIN	1000	64	6	1
00543	THU3	ORTH	EXTR	1100	28	7	1
00544	THU3	FAMP	CHST	1100	35	3	0
00545	THU3	ORTH	EXTR	1100	37	4	4
00546	THU3	FAMP	CHST	1100	39	2	1
00547	THU3	FAMP	MULT	1100	36	32	0
00548	THU3	ORTH	EXTR	1100	61	5	5
00549	THU3	FAMP	CHST	1200	27	2	1
00550	THU3	EMER	EXTR	1200	20	4	4
00551	THU3	WD3B	BE	1200	9	51	6
00552	THU3	PEDS	CHST	1200	83	3	1
00553	THU3	INTM	CHST	1300	40	2	6
00554	THU3	USDB	EXTR	1300	28	3	14
00555	THU3	FAMP	EXTR	1300	26	5	0
00556	THU3	ORTH	EXTR	1300	30	10	2
00557	THU3	ORTH	EXTR	1300	35	8	7
00558	THU3	ORTH	EXTR	1400	46	2	1
00559	THU3	ORTH	EXTR	1400	46	6	1
00560	THU3	ORTH	EXTR	1400	47	2	1
00561	THU3	ORTH	EXTR	1400	49	7	1
00562	THU3	GOPC	CHST	1400	43	4	2
00563	THU3	GOPC	ABD	1600	2	7	2
00564	THU3	EMER	SPIN	1600	2	10	0

```
  LIST FOR DAY='FRI4'
00565   FRI4 FAMP SPIN 0800     4    18     1
00566   FRI4 FAMP SPIN 0800    23    18     4
00567   FRI4 ORTH EXTR 0800    40     2     1
00568   FRI4 MEDX CHST 0800    32     2     1
00569   FRI4 PT   SPIN 0800    39    28     0
00570   FRI4 USDB CHST 0800    97     2    11
00571   FRI4 ORTH EXTR 0800   103     5     2
00572   FRI4 GOPC IVP  0900    75    43     2
00573   FRI4 PEDS CHST 0800   105     3     1
00574   FRI4 GOPC EXTR 0900    94     3     3
00575   FRI4 GOPC HEAD 0800   130     5     1
00576   FRI4 ORTH MULT 0900   101    10     1
00577   FRI4 EMER EXTR 1000    97     2     2
00578   FRI4 FAMP UGI  1000   110    35     2
00579   FRI4 FAMP EXTR 1000   100     3     1
00580   FRI4 FAMP SPIN 1100    95    12     9
00581   FRI4 ORTH EXTR 1100   111     3     1
00582   FRI4 EMER EXTR 1000   140     3     1
00583   FRI4 GOPC HEAD 1100    95     5     9
00584   FRI4 GOPC EXTR 1100   107     3     6
00585   FRI4 PEDS HEAD 1100   110     4     1
00586   FRI4 GOPC HEAD 1100    99     5     0
00587   FRI4 EMER MULT 1300    18    10     5
00588   FRI4 PEDS SPEC 1200    52    52     8
00589   FRI4 OBGY IVP  1300    55    30     2
00590   FRI4 WDSB CHST 1300   132     4     0
00591   FRI4 FAMP EXTR 1100   175     3     1
00592   FRI4 GOPC SPIN 1300   112    10     1
00593   FRI4 GOPC EXTR 1300   121     3     1
00594   FRI4 GOPC EXTR 1300   125     3     1
00595   FRI4 EMER EXTR 1500    15     2     4
00596   FRI4 GOPC EXTR 1400   100     2     3
00597   FRI4 PEDS MULT 1500    39    50     0
```

```
  LIST FOR DAY='MON4'
00598   MON4 ORTH SPIN 0800    15     3     2
00599   MON4 FAMP EXTR 0800    19     3     2
00600   MON4 GOPC HEAD 0800     6     7     6
00601   MON4 ORTH EXTR 0800    30    11     1
00602   MON4 ORTH EXTR 0800    36     2     9
00603   MON4 WD2B CHST 0800    38     3     2
00604   MON4 GOPC ABD  0800    37     6     2
00605   MON4 COMH CHST 0800    44     3     1
00606   MON4 ORTH EXTR 0800    48     6     4
00607   MON4 GOPC CHST 0800    57     5     0
00608   MON4 MEDX CHST 0800    60     1     1
00609   MON4 GOPC CHST 0800    55     2     6
00610   MON4 SURG BE   0900    38    35     1
00611   MON4 MEDX SPIN 1000    16     9     2
00612   MON4 GOPC EXTR 0800    93     6     6
00613   MON4 MEDX CHST 0800   112     1     1
00614   MON4 COMH CHST 0900   103     3     1
00615   MON4 SURG BE   1000    48    39     3
00616   MON4 EMER EXTR 0900   121     6     1
00617   MON4 GOPC EXTR 0900   127     5     2
00618   MON4 DENT HEAD 0900   134     7     1
00619   MON4 GOPC EXTR 0900   136     2     5
00620   MON4 SURG BE   1100    31    30     2
00621   MON4 GOPC SPIN 1100   146    11     1
00622   MON4 INTM CHST 1000   123     2     1
00623   MON4 FAMP EXTR 0900   164     6     1
00624   MON4 GOPC EXTR 1100    83     2     8
00625   MON4 GOPC CHST 1200    49     2     3
00626   MON4 GOPC MULT 1200    46     5     1
00627   MON4 PT   SPIN 1200    43     5     6
00628   MON4 EMER CHST 1300     7     2     6
00629   MON4 EMER HEAD 1200    44    10     1
00630   MON4 SURG SPIN 1200    64     2     6
00631   MON4 ORTH EXTR 1300    44     2     1
00632   MON4 GOPC EXTR 1300    24     2     6
00633   MON4 EMER EXTR 1300    27     5     1
00634   MON4 ORTH EXTR 1300    27     3    11
00635   MON4 OBGY SPEC 1300    38    25     5
00636   MON4 GOPC EXTR 1400    27     2    16
00637   MON4 GOPC MULT 1400    19    20     4
00638   MON4 WD3B SPEC 1500     6    35     0
```

LIST FOR DAY='TUE4'

00639	TUE4	WD3P	CHST	0800	5	9	1
00640	TUE4	ORTH	EXTR	0800	18	2	4
00641	TUE4	MEDX	CHST	0800	23	3	1
00642	TUE4	FAMP	EXTR	0800	23	3	11
00643	TUE4	DENT	HEAD	0800	22	6	4
00644	TUE4	ORTH	EXTR	0800	23	2	1
00645	TUE4	GOPC	EXTR	0800	23	2	6
00646	TUE4	GOPC	EXTR	0800	30	2	4
00647	TUE4	MEDX	CHST	0800	36	1	7
00648	TUE4	GOPC	EXTR	0800	40	16	18
00649	TUE4	INTM	BE	0900	38	27	8
00650	TUE4	INTM	CHST	0900	82	2	1
00651	TUE4	MEDX	CHST	0900	81	2	7
00652	TUE4	MEDX	IVP	1000	30	35	7
00653	TUE4	ORTH	EXTR	0900	125	3	1
00654	TUE4	GOPC	SPIN	0900	129	3	1
00655	TUE4	ORTH	EXTR	0900	126	5	5
00656	TUE4	EMER	EXTR	1000	60	4	1
00657	TUE4	MEDX	TOMO	1100	12	78	2
00658	TUE4	MEDX	CHST	0900	213	2	2
00659	TUE4	ORTH	EXTR	1000	142	2	0
00660	TUE4	ORTH	EXTR	1000	140	4	9
00661	TUE4	ORTH	EXTR	1100	129	2	2
00662	TUE4	INTM	CHST	1100	133	2	1
00663	TUE4	ORTH	EXTR	1100	136	2	2
00664	TUE4	GOPC	EXTR	1100	121	4	6
00665	TUE4	ORTH	EXTR	1100	129	1	0
00666	TUE4	PEDS	EXTR	1100	129	2	0
00667	TUE4	GOPC	CHST	1100	123	2	4
00668	TUE4	ORTH	MULT	1200	103	6	3
00669	TUE4	FAMP	SPIN	1200	107	20	5
00670	TUE4	ORTH	ARTH	1400	25	35	4
00671	TUE4	ORTH	EXTR	1200	154	3	4
00672	TUE4	WD2C	EXTR	1400	38	12	0
00673	TUE4	ALGY	HEAD	1500	18	4	1
00674	TUE4	EMER	EXTR	1500	18	4	3
00675	TUE4	GOPC	HEAD	1500	22	8	5
00676	TUE4	GOPC	EXTR	1500	18	8	2
00677	TUE4	GOPC	EXTR	1500	25	13	0

```
  LIST FOR DAY='WED4'
00678  WED4 WD3B CHST 0800     5     2     0
00679  WED4 MEDX CHST 0800     7     3     1
00680  WED4 ORTH EXTR 0800     9     3     1
00681  WED4 MEDX CHST 0800     6     2     6
00682  WED4 MEDX CHST 0800     6     5     1
00683  WED4 MEDX CHST 0800     5     3     3
00684  WED4 INTM SPIN 0800     3     8     3
00685  WED4 GOPC CHST 0800     3     5     0
00686  WED4 GOPC EXTR 0800     5     2     6
00687  WED4 MEDY CHST 0900     6     1     0
00688  WED4 GOP  CHST 0900     6     1     3
00689  WED4 GOPC EXTR 0900     3     5    27
00690  WED4 INTM IVP  0900    29    27     1
00691  WED4 GOPC EXTR 0900    48     4     0
00692  WED4 PEDS EXTR 0900    48     5     1
00693  WED4 PEDS EXTR 1000    30     9     0
00694  WED4 EMER EXTR 1000    24     2     1
00695  WED4 GOPC EXTR 1000    24     4     2
00696  WED4 FAMP EXTR 1000    27     3     4
00697  WED4 FAMP EXTR 1100     4     5     1
00698  WED4 EMER CHST 1100     1    10    19
00699  WED4 ORTH CHST 1100    23     2     1
00700  WED4 FAMP EXTR 1100    16     3    45
00701  WED4 EMER ABD  1100    91    60     2
00702  WED4 ORTH EXTR 1300    51     8     2
00703  WED4 GOPC CHST 1300    37     3     1
00704  WED4 GOPC CHST 1300    34     3     8
00705  WED4 MEDX SPIN 1300    26    15     4
00706  WED4 GOPC EXTR 1400    31     8     3
00707  WED4 EMER EXTR 1400    14     4     4
00708  WED4 GOPC EXTR 1400    17     1     1
00709  WED4 EMER EXTR 1400    15     3     2
00710  WED4 WD2C CHST 1500     2    11    10
00711  WED4 GOPC SPIN 1500    10     2     1
00712  WED4 INTM EXTR 1500    11     4     8
00713  WED4 ORTH EXTR 1500    11     6     4
00714  WED4 FAMP SPIN 1500     4    21     1
00715  WED4 FAMP EXTR 1500    20    13     0
```

LIST FOR DAY='THU4'

00716	THU4	MEDX	CHST	0800	12	4	2
00717	THU4	ORTH	EXTR	0800	18	8	0
00718	THU4	ORTH	EXTR	0800	24	7	2
00719	THU4	GOPC	SPIN	0800	32	4	1
00720	THU4	ORTH	EXTR	0800	30	5	1
00721	THU4	MEDX	CHST	0800	16	2	3
00722	THU4	PEDS	CHST	0800	18	4	8
00723	THU4	GOPC	EXTR	0800	16	9	7
00724	THU4	GOPC	EXTR	0900	9	3	14
00725	THU4	ORTH	TOMO	0900	36	48	1
00726	THU4	ORTH	EXTR	0900	52	16	1
00727	THU4	INTM	CHST	0900	60	1	0
00728	THU4	ORTH	EXTR	0900	53	8	3
00729	THU4	ORTH	SPIN	1000	49	14	0
00730	THU4	EMER	HEAD	1000	49	8	1
00731	THU4	EMER	EXTR	1100	21	2	2
00732	THU4	ORTH	EXTR	1100	20	5	1
00733	THU4	MEDX	CHST	1100	24	2	12
00734	THU4	GOPC	EXTR	1100	9	2	6
00735	THU4	ORTH	EXTR	1200	6	6	4
00736	THU4	GOPC	EXTR	1200	4	7	6
00737	THU4	MEDX	EXTR	1200	14	6	24
00738	THU4	MEDX	CHST	1200	24	12	1
00739	THU4	ORTH	EXTR	1300	13	9	2
00740	THU4	ORTH	EXTR	1300	14	2	2
00741	THU4	GOPC	CHST	1300	13	2	3
00742	THU4	GOPC	EXTR	1300	4	4	2
00743	THU4	WD2C	EXTR	1300	1	7	7
00744	THU4	FAMP	CHST	1400	7	1	3
00745	THU4	ORTH	EXTR	1400	10	6	10
00746	THU4	ORTH	EXTR	1400	10	5	1
00747	THU4	ORTH	EXTR	1400	13	5	5
00748	THU4	ORTH	EXTR	1400	19	5	17
00749	THU4	EMER	SPIN	1500	17	7	2
00750	THU4	EMER	EXTR	1500	5	1	1
00751	THU4	MEDX	CHST	1600	1	3	0

APPENDIX E

ESTIMATE OF WORKLOAD EXPECTED DURING THE EMU

AVERAGE NUMBER OF EXAMINATIONS EXPECTED PER FOUR-WEEK PERIOD
August 1986 - April 1987

Type of Examination	Aug-Oct	Nov-Jan	Feb-Apr
General X-Ray:			
Chest/Ribs	224	200	220
Extremeties	360	300	329
Head/Sinus	36	43	43
Spine	80	76	90
Kidneys/Ureters/Bladder	9	9	8
Abdominal Series	10	10	11
Multiple	19	18	23
Total	738	656	724
Fluoroscopic and Special			
Upper Gastrointestinal	25	29	23
Barium Enema	29	20	19
Barium Swallow	3	4	2
Gall Bladder	5	5	5
Small Bowel Follow Through	3	2	1
Arthrogram	2	2	2
Venogram	2	2	1
Intravenous Pyelogram	17	18	21
Tomogram	3	2	3
Xerogram	-	1	1
Other	5	6	7
Total	94	91	85
Mammograms	60	60	60

APPENDIX F

ESTIMATE OF EXPECTED AVERAGE WAITING TIME ALTERNATE SCHEDULING METHOD #2

TABLE 20

EXPECTED DISTRIBUTION OF PATIENT ARRIVALS ALTERNATE SCHEDULING METHOD #2

Arrival Hour	General X-Rays	Sched. F&S	Unsched. F&S	Total F&S
0800	187	-	1	1
0900	105	-	3	3
1000	91	-	1	1
1100	81	-	2	2
1200	61	-	4	4
1300	66	4	1	5
1400	61	2	3	5
1500	63	-	2	2
1600	23	-	-	-
Total	738	6	17	23

TABLE 21

EXPECTED AVERAGE EXAMINATION COMPLETION TIMES AND CUMULATIVE VARIANCE FROM SERVICE CAPACITY ALTERNATE SCHEDULING METHOD #2

Arrival Hour	Average Daily Arrivals		Average Time Required to Complete Examinations (In minutes)			Cumulative Variance from Service Capacity (In minutes)
	Gen.	F&S	Gen.	F&S	Total	
0800	9.35	0.05	92	2	94	+34
0900	5.25	0.15	51	7	58	+32
1000	4.55	0.05	45	2	47	+19
1100	4.05	0.10	40	5	45	+4
1200	3.05	0.20	30	9	39	-17
1300	3.30	0.25	32	11	43	-34
1400	3.05	0.25	30	11	41	-53
1500	3.15	0.10	31	5	36	-77
1600	1.15	--	11	--	--	-96

TABLE 22

DIFFERENCES IN AVERAGE EXAMINATION COMPLETION TIMES REQUIRED
ALTERNATE SCHEDULING METHOD #2
(In Minutes)

Arrival Hour	Study Period (Observed)	Alternate Method #1 (Expected)	Difference	Cummulative Difference
0800	105	94	-11	-11
0900	83	58	-25	-36
1000	67	47	-20	-56
1100	43	45	+2	-54

TABLE 23

ESTIMATE OF EXPECTED AVERAGE WAITING TIMES
ALTERNATE SCHEDULING METHOD #2
(In Minutes)

Arrival Hour	Study Period Average Patient Waiting Time (Observed)	Cumulative Difference in Average Examination Completion Time (+ or -)	Expected Average Patient Waiting Time
0800	47	-11	36
0900	87	-36	51
1000	94	-56	38
1100	79	-54	25

APPENDIX G

OPTIMAL SOLUTION COMPUTER PRINTOUT
ALTERNATE SCHEDULING METHOD #3

YOUR VARIABLES 1 THROUGH 10
SLACK VARIABLES 11 THROUGH 22

ANSWERS:
PRIMAL VARIABLES:

VARIABLES	VALUE
1	33.31249
2	20
4	6.666666
6	2.666667
7	2.666667
8	20
9	1.333333
10	80
11	1030
13	3.015633
15	4
17	2

DUAL VARIABLES:

VARIABLE	VALUE
1	0
2	1.21875
3	0
4	30.29167
5	0
6	11.5
7	0
8	86.875
9	75.83333
10	73.54167
11	147.2083
12	31.25

VALUE OF OBJECTIVE FUNCTION 11019.19

APPENDIX H

OPTIMAL SOLUTION COMPUTER PRINTOUT
ALTERNATE SCHEDULING METHOD #4

YOUR VARIABLES 1 THROUGH 10
SLACK VARIABLES 11 THROUGH 22

ANSWERS:
PRIMAL VARIABLES:

VARIABLES	VALUE
1	7.06249
2	20
4	6.666667
6	2.666667
7	2.666667
8	20
9	1.333333
10	80
11	1030
13	22.70313
15	4
17	2

DUAL VARIABLES:

VARIABLE	VALUE
1	0
2	1.21875
3	0
4	30.29167
5	0
6	11.5
7	0
8	86.875
9	75.83333
10	73.54167
11	147.2083
12	31.25

VALUE OF OBJECTIVE FUNCTION 9995.438

APPENDIX I

OPTIMAL SOLUTION COMPUTER PRINTOUT
ALTERNATE SCHEDULING METHOD #3
(25% Workload Increase)

YOUR VARIABLES 1 THROUGH 10
SLACK VARIABLES 11 THROUGH 22

ANSWERS:
PRIMAL VARIABLES:

VARIABLES	VALUE
2	24.66666
6	4
7	4
8	25.33334
9	1.333333
10	100
11	1770
13	25
14	.5000046
15	5
16	6
17	3

DUAL VARIABLES:

VARIABLE	VALUE
1	0
2	1.702128
3	0
4	0
5	0
6	0
7	0
8	57.87235
9	37.16313
10	44.53902
11	113.0497
12	11.9149

VALUE OF OBJECTIVE FUNCTION 11993.33

APPENDIX J

OPTIMAL SOLUTION COMPUTER PRINTOUT
ALTERNATE SCHEDULING METHOD #4
(25% Workload Increase)

YOUR VARIABLES 1 THROUGH 10
SLACK VARIABLES 11 THROUGH 22

ANSWERS:
PRIMAL VARIABLES:

VARIABLES	VALUE
2	6.794323
6	4
7	4
8	25.33334
9	1.333333
10	100
11	1770
13	35
14	13.90426
15	5
16	6
17	3

DUAL VARIABLES:

VARIABLE	VALUE
1	0
2	1.702128
3	0
4	0
5	0
6	0
7	0
8	57.87235
9	37.16313
10	44.53902
11	113.0497
12	11.9149

VALUE OF OBJECTIVE FUNCTION 10563.55

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